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DELAWARE ESTUARY COMPREHENSIVE STUDY. PRELIMINARY REPORT AND FINDINGS

Federal Water Pollution Control Administration
Philadelphia, Pennsylvania

July 1966

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DELAWARE ESTUARY
COMPREHENSIVE STUDY

PRELIMINARY REPORT
AND FINDINGS

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DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PHILADELPHIA, PA.

JULY 1966

DEPARTMENT OF THE INTERIOR

STEWART L. UDALL
SECRETARY

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

JAMES M. QUIGLEY
COMMISSIONER

DELAWARE ESTUARY COMPREHENSIVE STUDY
STAFF

Everett L. MacLeman, Project Director - To June, 1966
Edward V. Geismar, Acting Project Director
Robert V. Thomann, Technical Director

Alvin R. Morris, Chief, Field Operations
Wayne A. Blackard
Albert W. Bromberg
Billy L. DePrater
Robert W. Knight
David H. Stoltenberg
Darwin R. Wright

Matthew J. Sobel, Chief, Plans and Projections
Daniel J. FitzGerald
David H. Marks
George D. Pence, Jr.
William L. Richardson
Ethan T. Smith

Virginia C. Tobin, Adm. Assistant
Carol A. Cilwick
Ruth M. Lipman
Dorothy A. Townson

FOREWORD

The Delaware is a dirty river. This was not always its fate. In August 1609, Henry Hudson in his log of the voyages of the "Half Moon" noted that the Delaware is "... one of the finest, best and pleasantest rivers in the world." Early settlers wrote home to Europe of the great abundance of sturgeon in the river and made special note of its fish. As recently as the 1890's, commercial fishing in the Delaware was a $4 million business. The massive urbanization and industrialization of the twentieth century destroyed commercial fish, contaminated municipal water works, and closed bathing beaches along the Delaware.

For three gnerations pollution of the Delaware has been self-evident. However, up to now there has never been available a detailed analysis of that pollution; what it is, who is responsible for it, what might be done, and what it would cost to abate it.

In 1957-58, at the request of the Corps of Engineers, the Public Health Service made a preliminary study of pollution in the Delaware Estuary. This in turn led to the making of the comprehensive study covered by this report. The study was begun in 1961 by the Water Supply and Pollution Control Division of the Public Health Service, now the Federal Water Pollution Control Administration, at the request of the state and interstate pollution control agencies.

This is a preliminary report of that study. Its authors are the FWPCA engineers, scientists, and economists who conducted the study, but it reflects the contributions of numerous local and state officials as well as hundreds of public spirited citizens. The cost of the study was $1.2 million.

This expenditure of money and man power will be a wise and prudent investment if the purpose of the study is ultimately achieved. That purpose is to provide a blueprint for the enhancement of the waters of the Delaware.

This preliminary report suggests several alternate pollution control objectives for the Delaware Estuary. The final report will be published in the summer of 1967. That report will, of course, reflect editorial refinements and any additional views of the reviewing agencies. Hopefully, it will also contain an agreed upon set of pollution control objectives together with a cooperative plan for their full and early achievement.

June 27, 1966
Washington, D. C.

James M. Quigley, Commissioner
Federal Water Pollution Control
Administration
Department of the Interior

DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

DELAWARE ESTUARY COMPREHENSIVE STUDY PRELIMINARY REPORT AND FINDINGS

SUMMARY

INTRODUCTION

The water quality of the Delaware Estuary has been a matter of concern for many years.

During the late 1950's, State and interstate water pollution control agencies and the City of Philadelphia became increasingly concerned with the obvious severe pollution of the Delaware Estuary. They requested the Public Health Service's Division of Water Supply and Pollution Control, now the Federal Water Pollution Control Administration, to undertake a cooperative study to develop a comprehensive program for water pollution control in the Delaware Estuary under the provisions of the Federal Water Pollution Control Act. The Delaware Estuary Comprehensive Study (DECS) was thus undertaken in late 1961 in cooperation with the State regulatory agencies of New Jersey, Pennsylvania, and Delaware, the Delaware River Basin Commission, the City of Philadelphia, and other interested parties. The study area encompasses the Delaware Estuary from Trenton, New Jersey, to Liston Point, Delaware, including the estuarine reaches of its tributaries.

Three advisory committees helped to prepare this report. The Policy Advisory Committee included representatives of State, interstate, and Federal agencies having the legal power to abate pollution. The Technical Advisory Committee included representatives from agencies and installations participating in the work of the study and who were familiar with the technical aspects of water pollution control. The Water Use Advisory Committee was composed of four subcommittees: a) General Public, b) Industry, c) Local Government and Planning Agencies, and d) Recreation, Conservation, Fish and Wildlife. On all three committees, over 100 organizations providing over 200 participants cooperated throughout the study.

THE ECONOMIC ENVIRONMENT AND ITS WASTE INPUTS

The increase in population of the urbanized areas from 1950 to 1960 ranged between 24 and 51%, although the geographical units that make up the urbanized areas showed considerably greater variability. In the study area, the bulk of the population is served by municipal waste treatment plants, eight of which discharge over 90% of the area's discharged municipal oxygen demanding load.

During 1964 about 26,000 people were employed by the major firms designated as substantial waste dischargers. For the 18 major industrial waste sources, the estimated dollar value of output during 1964 was over 2 million dollars. Later reports will list the sources and magnitude of these discharges.

Organic waste loads are usually characterized by the amount of oxygen needed to stabilize the waste material. The total carbonaceous oxygen demanding waste load discharged to the estuary during 1964 is estimated about 1,000,000 lbs./day. About 65% of this discharge is from municipal discharges and 35% from direct industrial discharges. Additional oxygen demands result from a discharge of nitrogenous material from municipal and industrial sources (estimated at about 600,000 lb/day) and an oxygen demand of about 200,000 lb/day exerted by bottom deposits of sludge and mud. These bottom deposits appear to be the result of settleable material discharged from stormwater overflows and from spoil areas resulting from dredging operations. They are also caused by municipal and industrial waste effluents.

The vast majority of the municipal waste effluent flows are discharged without disinfection and consequently contain large concentrations of coliform bacteria. Overflows from combined sewerage systems also contribute bacteria to the estuary during times of high rainfall.

Several industrial dischargers are contributing significant quantities of acidity (estimated at 1,300,000 lb/day during the summer) to the estuary.

The major portion of the oxygen demanding loads discharged to the estuary is released after some waste reduction has taken place. During 1964 all municipal sources along the estuary gave at least primary waste treatment (about 30 to 40% removal of oxygen demanding load) and ranged up to a 90% removal level. Since waste reduction at an industrial plant may involve inplant modification, separation of cooling-process water, as well as a number of other techniques designed to reduce wastes peculiar to a given plant, the amount of industrial waste reductions along the estuary ranges from none (0% removal) to a high secondary-tertiary level (92%-98% removal of "raw" load). During 1964 it was estimated that, overall, the removal of all waste discharges along the estuary was about 50% of the "raw" load.

Population projections in the study area indicate increases of 30% between 1960 and 1975, and by 135% between 1960 and the year 2010. Total productivity as measured by dollar value of output would increase by about 45% between 1964 and 1975 and by almost 400% between 1964 and 2010. It is estimated that 1964 municipal "raw" waste load (about 1.2 million lb/day) will increase by 2.3 times (to 2.8 million lb/day) in 1975 and by almost 5 times (to 6.1 million lb/day) in 2010. Industrial "raw" waste loads in 1964 (about .7 million lb/day) are expected to almost double by 1975 (to about 1.2 million lb/day) and by 2010 will increase by greater than 6 times (to 4.6 million lb/day) the present waste load. Overall, the total municipal and industrial waste load prior to reduction is expected to more than double by 1975 and to be almost 5-1/2 times the 1964 load by 2010.

WATER QUALITY

The water quality of the estuary at Trenton, New Jersey, is generally excellent, but begins to deteriorate rapidly below that point. From Torresdale, Pennsylvania, to below the Pennsylvania-Delaware State Line the deterioration becomes extreme. As a result of waste discharges, dissolved oxygen is almost completely depleted in some locations and gases from anaerobic decomposition of organic deposits are produced regularly during the summer. Coliform bacteria concentrations are very high in this same stretch of river. Acid conditions in the river caused by industrial waste discharges have been observed for several miles above and below the Pennsylvania-Delaware State Line. Surface discoloration due to the release of oil from vessels and surrounding refineries is a common occurrence from Philadelphia to below the State Line. Overflows from combined sewerage systems result in a discharge of fecal matter and other offensive solids, floating material, and miscellaneous floatsam which would normally be trapped by the treatment plant. This material in the estuary represents one of the few remaining types of discharges that can seriously affect the aesthetics of the estuary by discharging visible evidence of raw sewage. The net result is a polluted waterway which depresses aesthetic values, reduces recreational, sport and commercial fishing, and inhibits municipal and industrial water uses.

Intrusion of salt water from the bay, while not caused by pollutional discharges, also imposes a limitation on municipal and industrial water uses during periods of extended low flows.

A mathematical modeling of the Delaware Estuary (i.e., categorizing the estuary in specific mathematical terms for a computer) permitted the evaluation of the independent effects of each of the aforementioned waste discharges on the present level of quality, and afforded an opportunity to formulate alternative control programs to achieve specific objectives. This approach required the development and application of new techniques of systems analysis, operation research, and computer utilization to provide a rational basis for water quality improvement.

WATER USE

The amount of surface and ground water withdrawn by the 35 principal municipalities in the study area during 1963 was approximately 550,000,000 gallons daily. The Torresdale Water Treatment Plant of the City of Philadelphia was the largest water user, withdrawing about 200,000,000 gallons a day from the estuary proper.

Industrial water demand is about 5 billion gallons a day, of which about 98% comes from surface water. Almost 95% of this total industrial demand is used for cooling purposes; the rest is utilized in processing or for sanitary purposes. Of any single industrial type, the electric power generating plants use the greatest volume of water, about 3 billion gallons per day.

Present recreational uses of the estuary are limited, but include water skiing, pleasure boating, sport fishing, and a small amount of unsanctioned swimming. All of these activities are severely restricted by poor water quality and limited access.

During 1964-65, only about 23% of the boating capacity along the length of the estuary was used, owing to lack of access ramps and the presence of floating debris. Fishing was estimated at only about 8% of possible total capacity because the only locations where the water is good enought to hold any promise of successful fishing are at the extreme ends of the study area and therefore at a considerable distance from the large centers of population. The upper area between Trenton and Florence, N.J., a distance of about 8 miles, is estimated to support 60,000 activity days annually valued at $135,000. One activity day is a visit by one person to a recreation area during any reasonable portion of a 24-hour period. The lower area from Delaware City, Delaware, to Liston Point, Del., about 7 miles, is estimated to support 70,000 activity days valued at about $160,000 annually. Sanctioned swimming, as noted, is entirely absent along the estuary since municipal and industrial waste discharges make water contact sports hazardous to health and aesthetically unattractive.

Shad, sturgeon, striped bass, weakfish, and white perch were once commercially important in the study area. The peak period for the Delaware Estuary fisheries was between 1885 and 1900; at that time the annual catch by 4,000 fishermen amounted to 25 million pounds, worth about $4.5 million at today's prices. Shortly after the turn of the century, the annual harvest plummeted and the decline has continued. At present, the annual harvest is approximately 80,000 pounds, worth only about $14,000. Reasons for this decline are attributed to (1) industrial and municipal waste discharges into the estuary which resulted in extremely poor water quality conditions, (2) improper fisheries management allowing over-fishing, (3) introduction of predaceous species into the upper river, and (4) siltation (from farmland, surburban development, and river dredging operations) which covered spawning areas and limited production of fish food organisms.

Recently, the Atlantic Menhaden fishery has become extremely important as a source of oil, domestic animal feed supplements and fertilizer. The value of the menhaden from the estuary is estimated at about $1.4 million annually.

The only wildlife associated with the estuary are water fowl who use the tidal marshes bordering the river. Virtually all areas where water fowl could get adequate cover and food have been eliminated between Trenton and the Pennsylvania-Delaware State Line because of extensive industrial and municipal development.

In the lower part of the study area there are still approximately 21,000 acres of tidal marsh in New Jersey and 18,000 in Delaware. Water fowl such as ducks, teal, and Canada geese use these areas primarily as resting grounds during the Spring and Fall migration flights, although some limited nesting populations are present.

WATER QUALITY IMPROVEMENT

Members of the Water Use Advisory Committee were queried concerning possible swimming areas, desirable fishing locations, community desires on withdrawal of water from the estuary, and industrial desires on water use. The members of the Committee were also asked to suggest water quality criteria for the various water uses. Based in part on their responses, possible alternatives to improve water quality were reduced to five sets of water use and water quality objectives.

They ranged from maximum feasible enhancement of the river using current waste treatment technology (designated Objective Set I) to maintaining present (1964) levels of use and quality (designated Objective Set V). Objective Sets II, III, and IV were intermediate. The sets delineate reaches of the river where various water uses would be made suitable from a water quality standpoint. Twelve quality parameters were considered for each set. In summary, the five water use/quality objective sets are:

Objective Set I. This set would provide the greatest increase in water use and water quality. Water contact recreation is indicated in the upper and lower reaches of the estuary. Sport and commercial fishing were placed at relatively high levels consistent with the make-up of the region. A minimum daily average dissolved oxygen (DO) goal of 6.0 mg/l is included for anadromous fish passage during the spring and fall periods. Thus, anadromous fish passage is included as a definitive part of the water quality management program. Fresh water inflow control would be necessary to repulse high chloride concentrations to Chester, Pa., thereby creating a potential municipal and industrial water supply use.

Objective Set II. The area of water contact recreation is reduced somewhat from that of Objective Set I (OS-I). A reduction in dissolved oxygen (DO) is considered to result in a conconcomitant reduction in sport and commercial fishing. DO goals for anadromous fish passage remain as in OS-I. Chloride control would be necessary to prevent salt water intrusion above the Schuylkill River.

Objective Set III. This is similar in all respects to OS-II except for the following three changes. First, the specific DO crtieria for anadromous fish passage is not imposed. However, substantial increases in anadromous fish passage will result from the treatment requirements imposed to control DO during the summer. Second, a general decrease in the sport and commercial fishing potential is imposed through a lowering of the DO requirements. Third, the quality objectives for municipal water supply are reduced.

Objective Set IV. This set represents a slight increase over present levels in water contact recreation and fishing in the lower reaches of the estuary. Generally, quality requirements are increased slightly over 1964 conditions, representing a minimally enhanced environment.

Objective Set V. This set represents a maintenance of 1964 conditions, that is, a prevention of further water quality deterioration.

Four different waste reduction schemes were evaluated for each set. These were:

Uniform waste reduction (all sources treat to the same level).
Two different configurations of equal waste reduction by estuary zones.
Reduction of wastes by municipalities and industries as separate categories.
A program of cost minimization where all sources are required to remove wastes in accordance with location, expense and magnitude of load.

Other alternatives such as piping of wastes out of the estuary area, flow regulation and instream aeration were also evaluated. The costs of achieving the Objectives were evaluated; the benefits were described and, when possible, were quantitatively evaluated. This information was provided to all members of all committees of the DECS, so that, throughout the entire decision making process, full advantage could be made of all available technical information during the formation of a final set of use-quality objectives.

COSTS

To achieve Objective Set I, which calls for a summer average dissolved oxygen level of about 4.5 mg/l in the critical zones and 6 mg/l during the spring and fall fish runs would require about 92-98% removal of all carbonaceous waste sources plus instream aeration. An estuary-wide residual of about 100,000 lb/day of oxygen demanding wastes would be allowed. There is significant uncertainty as to the ability to achieve these reductions over the entire estuary. The program requires large scale utilization of advanced waste treatment and reduction processes, which is not deemed technically feasible at this time. The estimated total (capital and operation and maintenance) cost of removal to achieve and maintain this Objective Set (to 1975-1980) is about $490 million. This includes the reduction of oxygen demanding wastes as well as disinfection for bacterial control, but excludes any cost associated with reservoir storage for chloride control.

The achievement and maintenance of Objective Set II (e.g. summer average dissolved oxygen of 4 mg/l in the critical sections of the estuary) to the period 1975-1980 is estimated to cost between about $230 and $330 million depending on the particular type of waste reduction program. An overall residual load of about 200,000 lb/day would be allowed resulting in approximately 90% removal of the present waste load with the distribution of the load depending on the control program (e.g. uniform treatment, zoned treatment, or cost minimization).

Objective Set III, which is similar in many respects to Objective Set II, calls for a summer average dissolved oxygen of 3 mg/l in the critical sections. To achieve and maintain such water quality objectives to 1975-1980 would cost between $130 and $180 million. About 500,000 lb/day of organic material would be the allowable total discharge. This would represent an overall removal of about 75% of the present load. The actual removals for each source would again depend on the control program.

Objective Set IV, which represents a minimal enhancement over present water quality conditions calls for a summer average dissolved oxygen in the critical section of 2.5 mg/l. The estimated total cost of this objective, including the achievement of all water quality parameters, ranges from $100 to about $150 million.

It is estimated that the maintenance of present conditions, OS-V, in the face of increasing industrial and population growth would cost about $30 million. These total costs are summarized in the following table:

TABLE 1

Objective Set	Estimated Cost* Millions of Dollars (1975-1980)
I	460
II	200-300
III	100-150
IV	70-120

*Does not include maintenance of present conditions -- $30 million.

After the costs and benefits of the Objective Sets were evaluated the Water Use Advisory Committee held numerous meetings and discussions; and circulated correspondence among all members of each of the four subcommittees. Each subcommittee chairman was able to arrive at a consensus which represented at least the general attitudes and desires of his group. The members of the WUAC then met and arrived at a consensus of Objective Set III as the final recommendation of the WUAC to the Delaware Estuary Comprehensive Study.

A major concern was the role of anadromous fish passage in Objective Sets II and III. At this point an intensive investigation of the waste control programs of OS-II and OS-III as related to anadromous fish passage was carried out. Elements considered were passage period, time and distribution of passage, estimated survival rates at different dissolved oxygen levels, fish gender, forecasted dissolved oxygen profiles, and time series under various flow conditions with various waste loadings. These analyses indicate that during drought conditions (a one in 25 year low flow condition) the migrating shad currently have 20 per cent chance of survival. Under Objective Set III and a similar drought condition, it is estimated that the total upstream migrating shad would have about 80% chance of survival. Under OS-II this would increase to about a 90% chance of survival. For an average flow year, and present quality conditions, it is estimated that the shad have approximately a 60% survival rate while under Objective Set III this would increase to 85% and under Objective Set II to approximately 95% survival.

To maintain any of the water quality objectives for the period 1975 to 1985, it is estimated that the region would have to spend an additional 5 to 7-1/2 million dollars per year. These funds would be required to offset the increases in waste loading as a result of population growth and industrial expansion. By 1975 overall treatment levels to maintain Objective Set III would approach 90%, and for Objective Set II would approach 93%, of the estimated raw waste loads. By the year 2010, the estimates of waste loadings before treatment or reduction are so large that 96 to 99% waste removal would be necessary to maintain the objectives. It appears then, that by about 1990 additional waste treatment or reduction by present technology to maintain a specific objective may become prohibitively expensive and other schemes would have to be examined. These would include, for example, water recycling and reuse, the piping of wastes out of the critical areas, and the large scale use of mechanical instream aerators, all of which may become more feasible alternatives during the period 1985-1990 than attempting to achieve even higher waste reduction levels by classical means. New technology in waste reduction, however, would aid in alleviating the situation.

BENEFITS

The benefits from improved water quality will be substantial. The protection of the area's water resources, including the preservation and enhancement of fish and wildlife, and protection of the region's general health and welfare through expansion of recreational facilities would be directly related to the level of water quality improvement. At the present time it is not possible to quantify in monetary terms all of the benefits that would accrue to a region as a result of a water quality improvement program. However, every attempt was made as part of the DECS to determine those portions of the total benefits that are quantifiable; the remaining benefits are described in qualitative terms.

In the area of recreational benefits, three general categories were considered: 1) swimming, 2) boating, and 3) sport fishing. The analyses indicate a tremendous latent recreational demand in the estuary region that to some extent could be satisfied by improved water quality. It is estimated that during the period 1975-1980 the increase in total demand for the whole region over the present demand would be about 43 million activity days per year and by the year 2010 would increase to almost 100 million activity days per year.

Demand analyses have shown that the estuary could absorb a significant portion of this demand. With improved water quality, new areas would be made suitable for swimming, for other forms of water contact recreation, and for such non-water contact recreation as sports fishing.

In order to compute the monetary value associated with the demand under each objective set, a number of factors were considered (e.g., capacity of the estuary, the part of the total demand that the estuary could be expected to fulfill, and the application of monetary unit values to the total participating demand). Increases in anadromous fish passage would provide an outstanding sport fishing opportunity in the basin above Trenton. The size of the adult migrating shad (4-5 pounds) that reaches the upper headwaters makes it an excellent game fish for sporting enthusiasts; water quality improvement in the estuary therefore affects a highly desirable use over 100 miles from the point of control. The analyses indicate that the increase in direct quantifiable recreational benefit in present dollars for Objective Set I would range between 160 and 350 million; for Objective Set II between 140 and 320 million; for Objective Set III between 130 and 310 million; and for Objective Set IV between 120 and 280 million. The relatively wide range of benefit estimates results from the difficulty of accurately evaluating their dollar values.

As the water quality improves, a concurrent improvement in commercial fishing opportunity is expected to occur. It is estimated, especially for Objective Sets I, II and III, that there will be a substantial increase in the number of anadromous fish, thereby providing an opportunity for increased commercial fishing. The catch of menhaden is expected to increase along with other finfish such as striped bass, weakfish, and bluefish. Two capacities of the lower portion of the area will be improved: a) as a nursery area for young fish which subsequently migrate into Delaware Bay and form a large part of the sport and commercial fishing activity there, and b) as protection for aquatic organisms which serve directly and indirectly as food for fish which are harvested in abundance elsewhere. For the three categories of commercial fishing: a) shad, b) menhaden, and c) other finfish, estimated were made of the direct monetary benefits. These show incremental benefits ranging from about 5 million dollars (present value) under Objective Set IV to over 10 million dollars under Objective Set I.

In regard to municipal water supplies, the major source that would benefit from improved quality is the Torresdale Water Treatment Plant of Philadelphia. It is probable, however, that monetary benefits in terms of dollar savings and treatment costs at this plant will be relatively small at all Objective Sets. There will undoubtedly, however, be a substantial reduction of taste and odor problems which will greatly increase the ability of the plant to produce a more palatable drinking water. For industrial water use, positive benefits will result primarily from chloride reduction which accompanies increased fresh water inflow. These benefits are not included in this summary. In general, the industrial community indicates a low degree of sensitivity to water quality except for chlorides and dissolved oxygen. For both of these variables, the location of the industry, the quality of the estuarine intake water, and the industrial type are all important considerations. The results indicate an increase in benefits because of chloride control which is not, however, a function of any waste reduction programs. The response from the industrial community relative to oxygen indicated that if the DO goes up (usually a benefit for most other water uses), the cost to industry increases. This is primarily due to corrosion at higher DO levels. Therefore, the results indicate a negative benefit (cost) to industrial water users associated with increased DO. These negative benefits (costs) range from 5 million dollars for Objective Set IV to 15 million dollars for Objective Set I.

In addition to the preceding estimates of measurable benefits, there are numerous other uses that will be improved as a result of increased water quality. However, the nature of these increases in use is such that monetary estimates of the benefits cannot be made. Increased water quality will improve the value of property adjacent to the estuary by providing a watercourse that is more aesthetically pleasing. Similarly, picnic areas and parks along the river will be enhanced due to the presence of a more desirable body of water. Increased water quality reduces the risk of damage to piers, bridge abutments and vessels. Finally, the quantitative analyses in this Summary do not include the influence of secondary effects on the regional economy. For example, a unit of monetary benefit associated with commercial fishing use might be expected to generate at least an extra 15% in other benefits due to the interrelationship between the commercial fisherman and the remainder of the economy. This may occur in the form of increased wages, additional capital investment or increased use of trades and services.

The above benefit analyses can be summarized as follows:

For Objective Set IV, which represents a relatively slight increase in water quality, the range of estimated increase in quantifiable benefits is from 120 to 280 million dollars. As the objective is raised to Set III, the estimated range in benefits is from 130 to 310 million dollars. A further increase in water quality to Objective Set II results in a relatively small increase in benefits; from 140 to 320 million dollars. Finally, the water uses that are associated with Objective Set I are estimated to have a range of quantifiable benefits from 160 to 350 million dollars.

GUIDELINES FOR IMPLEMENTATION

The successful achievement of any of the water quality objectives requires a large scale, well budgeted, clearly outlined implementation program. The effort should include 1) an up-to-date inventory of the various waste loads to the system as a means of checking compliance with the requirements of the program, 2) a continuing estimate of future trends, and 3) a continuing determination of the costs and benefits of the control program. The physical processes that govern the cause and effect relationships between waste inputs and water quality should be continually re-examined. Knowledge of existing water quality and water use conditions is extremely important as a measure of program success and as a warning of long or short term conditions that might impair proposed uses and thus require additional waste control measures. A continual evaluation of the various waste water alternatives that are available is necessary. This requires a thorough investigation and knowledge of the types of water quality control mechanisms that are available, including costs and difficulty of administration. The evaluation of the effects of these mechanisms on the present and future economy of the region may require investigations.

Implementation can best be accomplished through the continued cooperation of all concerned, with the DRBC assuming the primary coordination and decision-making functions for the region. The FWPCA will continue to provide forecasting services and evaluation of water quality control alternatives, including costs and benefits and other analytical procedures, passing on recommendations to the DRBC through its advisory committees on policy and technical matters. Similarly, the States through the DRBC advisory committees can provide a policy and technical input as well as bear the burden of obtaining the basic data on water quality and waste loads.

ADDITIONAL STUDY REQUIREMENTS

Although a considerable amount of detailed investigation was carried out as part of the DECS, several areas that were uncovered during the Project could not be fully pursued because of time and resource constraints. Investigations of some of these areas were limited to the specific needs of the study, and they require further evaluation to fully understand the particular phenomena.

There are numerous indications at the present time that additional effort should be directed to:

1) Determine the interaction between the estuary and the bay so the effect of proposed control schemes in the estuary area on the bay could be determined.

2) To develop a plan of protection for present and future commercial and recreational uses of the bay.

Many water quality problems are relatively short term and transient in nature. As indicated throughout the study, there is a pressing need for specific DO control during times of anadromous fish passage to counteract periodic undesirable water quality conditions. The feasibility of large scale aeration should be evaluated. This should include, investigation into its costs, effectiveness, possible nuisance effects as well as oxygen transfer rates. Other transient water quality control problems arise from the accidental dumping of waste material. Additional study is required to determine the most effective control measure or combination of measures that can be employed under that type of situation.

Since overflows from combined sewerage systems are one of the last remaining violations of the aesthetics of the estuary, efforts should be made to initiate a stormwater overflow control project to experiment with new methods for intercepting the objectionable material discharged as a part of the combined sewer overflow. The region should therefore avail itself of the opportunities under Section 6 of the Federal Water Pollution Control Act, as amended.

Further detailed study should be made of the allocation of the costs of the water pollution control program, including investigation of effluent charges as a means of distributing costs and as a means of providing a constant incentive for the reduction of wastes. Because of the relatively sensitive nature of a study of this type, a thorough exposition of all opinions and facts should be an integral part of the investigation.

Study is also required to insure that better water uses made possible by improved water quality would indeed be realized - for example, close coordination to plan and construct necessary peripheral facilities (access points, parking areas).

Finally, further study is required concerning the benefits, direct and indirect, monetarily quantifiable and qualitatively descriptive of improved water quality. These studies should include possible increases in land valuations as a result of increased water quality, and values accruing to the region from expanded recreational facilities and higher levels of commercial water based economic activity.

TABLE OF CONTENTS

Page

FOREWORD i

SUMMARY iii

CHAPTER 1 - INTRODUCTION

Background and Authorization for Study 1
Scope of Report 2
Objectives of Delaware Estuary Comprehensive Study 2
Acknowledgment 5

CHAPTER 2 - DESCRIPTION OF STUDY AREA

Location and Boundaries 7
Geography and Topography 7
Geology 9
Climate 9
Principal Communities and Industries 10
Hydrology 11

CHAPTER 3 - THE ECONOMIC ENIVORNMENT AND ITS WASTE INPUTS

Population 15
Employment, Production, Industry Types 18
Present Waste Loads 20
Economic Trends and Outlooks 25
Future Waste Loads Before Reduction 28

CHAPTER 4 - WATER QUALITY

Present Water Quality 33
Mathematical Analysis of Cause and Effect Relationships 38

CHAPTER 5 - WATER USES

Municipal Water Supply 43
Industrial Water Supply 45
Recreation 48
Fish and Wildlife 50

CHAPTER 6 - WATER QUALITY IMPROVEMENT

Water Use and Water Quality Goals 53
Alternative Programs to Secure Desired Water Quality Objectives 61
Costs of Alternate Programs 62
Maintenance of Objectives 69
Benefits of Increased Water Use 71

TABLE OF CONTENTS (Cont'd)

Page

CHAPTER 7 - IMPLEMENTATION

Guidelines for Implementation 83
Delaware River Basin Commission 85
Federal Water Pollution Control Administration 86
States 88

CHAPTER 8 - ADDITIONAL STUDY REQUIREMENTS

Delaware Bay Study 91
Investigation of Transient Control Measures 92
Stormwater Overflows 92
Investigation of Secondary Effects 93
Cost Allocation 93
Management of the Contiguous Environment 93
Benefits Analysis 94

APPENDICES

I - DECS COMMITTEE STRUCTURE
II - WATER USE ADVISORY COMMITTEE TO THE DELAWARE ESTUARY STUDY - FINAL RECOMMENDATION

LIST OF FIGURES

Page

1 The Delaware Estuary and Location of the Delaware River Basin 3

2 The DECS Advisory Committee Structure 4

3 The Study Area of the DECS 8

4 Estimated Monthly Flow Distributions for Delaware River at Trenton, N. J. 11

5 Example of Current Velocities in the Delaware Estuary at Tacony-Palmyra Bridge 13

6 Delaware Estuary Urbanized Areas in 1960 16

7 Urbanized Area Populations, 1950-1960 17

8 Identification of Industries by SIC Number . . . 19

9 1964 Employment in Two-Digit SIC's for Direct Discharging Industries 20

10 1964 Dollar Value of Output in Two-Digit SIC's for Direct Discharging Industries 21

11 Carbonaceous Oxygen Demand Discharges to the Delaware Estuary - 1964 22

12 Municipal and Industrial Carbonaceous Oxygen Demand Discharges Along the Delaware Estuary - 1964 23

13 Simulated Stormwater Overflow Distribution Over Time 25

14 Economic Functional Dependence in the Delaware Estuary Region 26

15 Estimated Population Tributary to Major Water Pollution Control Plants Along the Delaware Estuary, 1960-2010 26

16 Estimated Employment in Major Direct Discharging Industries Along the Delaware Estuary, 1964-2010 27

FIGURES (Cont'd)

Page

17 Estimated Value of Output for Major Director Discharging Industries Along the Delaware Estuary, 1964-2010 28

18 Projected Waste Loads Before Reduction - Carbonaceous Oxygen Demand (#/Day) 29

19 Systems Diagram of Industrial Production - Waste Discharge Process 31

20 Map of Delaware Estuary Showing Section Breakdown 34

21 Profile of Average Summer (June-August 1964) Dissolved Oxygen (mg/l) 36

22 Profile of Geometric Mean Summer (June-August 1964) Coliform Bacteria (#/100 ml) 36

23 Profile of Average Summer (June-August 1964) Alkalinity (mg/l) 37

24 Maximum Chloride (mg/l) Intrusion During 1964 . 37

25 Dissolved Oxygen System 38

26 Effect on Stream BOD of 100,000# of BOD Discharged into Section 10 39

27 Effect on DO of 100,000# of BOD Discharged into Section 10 40

28 Effect on DO in Section 13 of Removal of Carbonaceous Oxygen Demand 40

29 Effect on DO of 200,000# of BOD Discharged at One Time into Section 15 41

30 System for Chlorides 42

31 Effect on Chlorides in Section 18 of Simulated Input of 15,000 cfs at Trenton, N. J. for 8 Days 42

32 Distribution of Municipal Water Supply by State and Source 43

FIGURES (Cont'd)

Page

33 Municipal Water Supply Points and Origins of Withdrawals 44

34 Distribution of Industrial Water Demand Along the Delaware Estuary 45

35 Total Industrial Water Use in Study Area 46

36 Industrial Water Use in Study Area Excluding Electrical Utilities 46

37 Historical Variation in Finfish and Shad Harvests 50

38 Information Flow Between DECS and Advisory Committees 54

39 Water Uses for Objective Sets I-V 55

40 Estimated Total (Male & Female) Upstream Shad Passage for OS-II, III & V (Present Conditions) 60

41 A-Zone and B-Zone Configuration Used for Evaluation of Alternative Programs 64

42 Index of Industrial Self Supplied Water Use From Surface Sources 73

43 Industrial Dissolved Oxygen Incremental Negative Benefit (Cost) in 1964 Dollars 74

44 Estimated Future Recreation Demand in the Delaware Estuary Region 75

45 Present Value (1964) of Recreation Benefits from Demand Satisfied by the Delaware Estuary . . . 78

46 Water Quality Management System 83

LIST OF TABLES

		Page
1	Tons of Commodities Shipped from Trenton, Philadelphia, and Wilmington Areas (1963)	10
2	Major Gaged Tributaries	12
3	Tidal Height Ranges	13
4	Characteristics of Municipal Sewerage Systems, 1957-1960	18
5	Dissolved Oxygen Data for 1964	35
6	Industrial Water Use Comparison in Study Area - 1963	47
7	Comparison of Present Capacity and Use - 1965 . . .	48
8	Water Quality Goals for Objective Set I	56
9	Water Quality Goals for Objective Set II	57
10	Water Quality Goals for Objective Set III	57
11	Water Quality Goals for Objective Set IV	58
12	Present Water Quality - Objective Set V	58
13	Estimated Total (Male & Female) Upstream Shad Passage	60
14	Summary of Total Costs of Dissolved Oxygen Objectives	63
15	Summary of Waste Reduction Requirements to Meet Dissolved Oxygen Objectives	65
16	Estimated Total Costs of Objective Sets	66
17	Capital Costs for Attainment of Objectives 1) By Piping of Wastes out of the Estuary, 2) By Treatment of Wastes at the Source	68

LIST OF TABLES (Cont'd)

Page

18 Estimated Total Cost to Reach DO Objectives By Mechanical Aeration 69

19 Average Allowable Carbonaceous Oxygen Demand . . 69

20 Estimated Recreational Benefits (1975-1980) . . 77

21 Estimated Net Commercial Fishing Benefits . . . 80

CHAPTER 1

INTRODUCTION

BACKGROUND AND AUTHORIZATION FOR STUDY

The water quality of the Delaware Estuary has been a matter of concern for many years. In 1957 and 1958 the Public Health Service, Department of Health, Education, and Welfare, conducted several field studies and wrote a water quality report describing the Delaware River. This study was part of the Corps of Engineers' comprehensive water resources investigation of the Delaware River Basin. The report, entitled "Report on the Comprehensive Survey of the Delaware Basin, Appendix C, Municipal and Industrial Water Use and Stream Quality", recognized that the quality of the estuary portion of the Delaware was undesirable. Time and funds were not sufficient for a proper detailed water quality study of the estuary.

It was evident, however, from the available data that the quality of the water in the estuary, particularly the strech from Philadelphia, Penna. to the Pennsylvania-Delaware state line was poor, especially during the warmer summer months. State and interstate water pollution control agencies concerned with the obvious severe pollution of the estuaryasked the Public Health Service, in accordance with Section 3(a) of Public Law 660, the Federal Water Pollution Control Act, as amended, to undertake a cooperative study, to develop a comprehensive program for water pollution control in the Delaware Estuary.

Section 3(a), Comprehensive Programs for Water Pollution Control, states that:

> "The Secretary shall, after careful investigation, and in cooperation with other Federal agencies, with state water pollution control agencies and interstate agencies, and with the municipalities and industries involved, prepare or develop comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground waters. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life and wildlife, recreational purposes, agricultural, industrial, and other legitimate uses...."

In late 1961, the Delaware Estuary Comprehensive Study (DECS) was undertaken in cooperation with the Interstate Commission on the Delaware and its subsequent successor, the Delaware River Basin Commission, the Delaware Water Pollution Commission, the New Jersey Department of Health, the Pennsylvania Department of Health, the City of Philadelphia Water Department and several other agencies. On January 1, 1966, the water pollution control activities of the Public Health Service of the Department of Health, Education, and Welfare were transferred to the Federal Water Pollution Control Administration, which during May, 1966, became an agency of the Department of the Interior.

SCOPE OF REPORT

The study covers the length of the Delaware River from Trenton, New Jersey, to Liston Point, Delaware. This 86 mile stretch of river, known as the estuary because of the influence of astronomically caused tidal motions, is encompassed by one of the most heavily populated and industrialized areas in the country. Figure 1 is a map of the estuary and location of the Delaware River Basin.

This preliminary report consists of a general review of the study, together with the alternative water quality goals, costs and benefits and control schemes that were considered. A more detailed technical report is being prepared presenting the various analyses that were performed during the development of the Comprehensive Program.

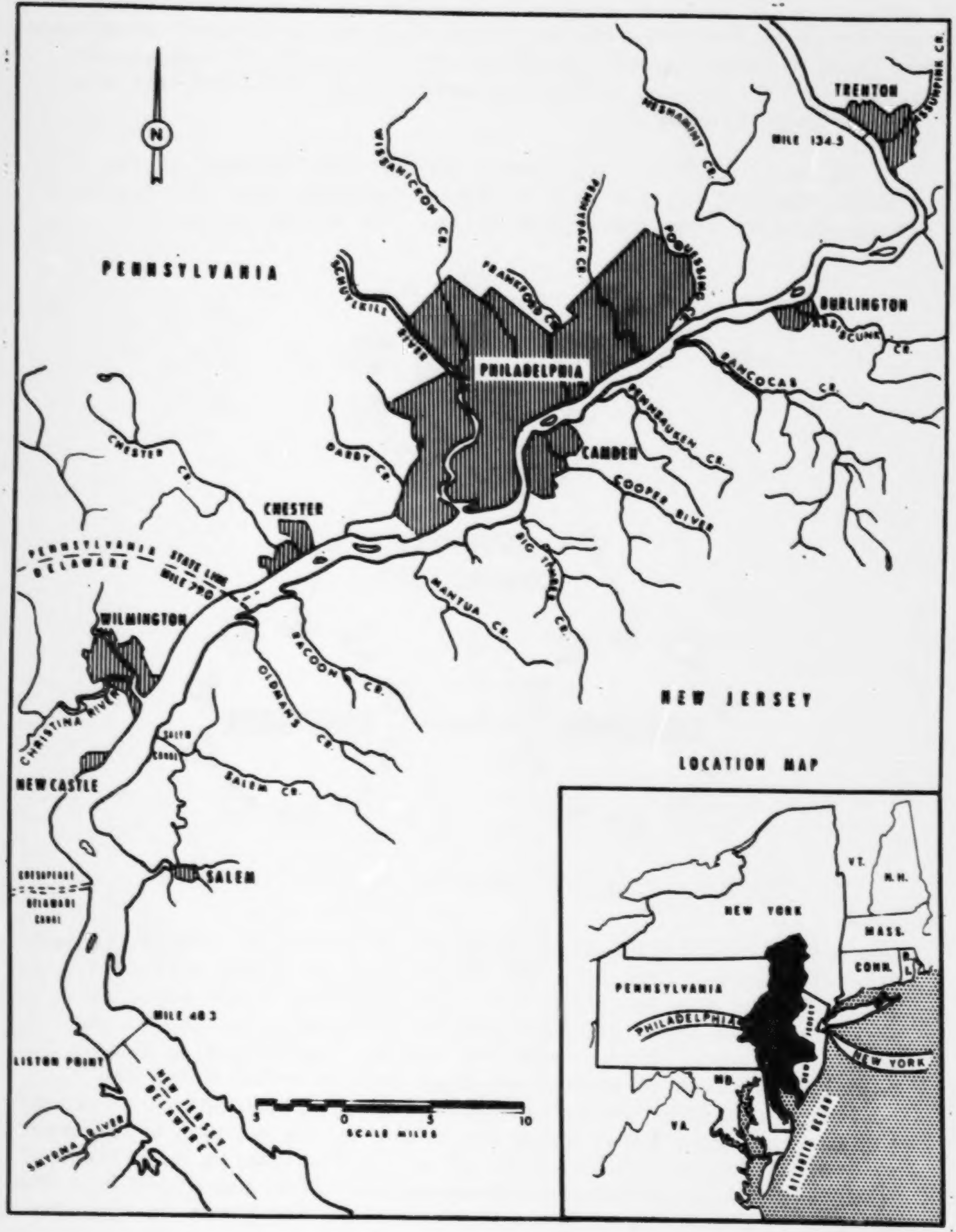
OBJECTIVES OF THE DELAWARE ESTUARY COMPREHENSIVE STUDY

The objectives of the study are as follows:

a) Determine the cause and effect relationships between pollution from any source and the present deteriorated quality of water in the estuary.

b) Develop methods of water quality management including the development of techniques of forecasting the variations in water quality due to natural man-made causes.

c) Prepare a comprehensive program for the improvement and maintenance of water quality in the estuary including the waste removals and other control devices necessary to manage the quality of water in the estuary for municipal, industrial and agricultural water use, and for fisheries, recreation and wildlife propagation.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LOCATION MAP
VT.
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NEW YORK
MASS.
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R.I.
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PHILADELPHIA
NEW JERSEY
NEW YORK
MD.
VA.
DELAWARE
OCEAN

FIGURE 1. - The Delaware Estuary and location of the Delaware River Basin, river mile 0.0 = mouth of Delaware Bay.

The results of the study provide a set of operational procedures to be followed in the achievement of a specified water quality objective. In the maintenance of the objective, cognizance is given to the expected growth of the municipal and industrial sectors of the region in the immediate future (1975-80) and the longer range (year 2010).

In order to more fully carry out the requirements of the Federal Water Pollution Control Act as amended, the DECS formed three advisory committees (Figure 2). The Policy Advisory Committee (PAC) includes representatives of state, interstate and federal agencies that have the legal power to abate pollution. Membership of the Technical Advisory Committee (TAC) includes personnel from agencies and installations participating in the work of the work of the study and who are familiar with the technical aspects of water pollution control. The Water Use Advisory Committee (WUAC) is composed of four subcommittees representing the major water using interests in the estuary study area: a) General Public, b) Industry, c) Local Governments and Planning Agencies, and d) Recreation, Conservation, Fish and Wildlife. The details of the Advisory Committee structure are given in Appendix I to this report.

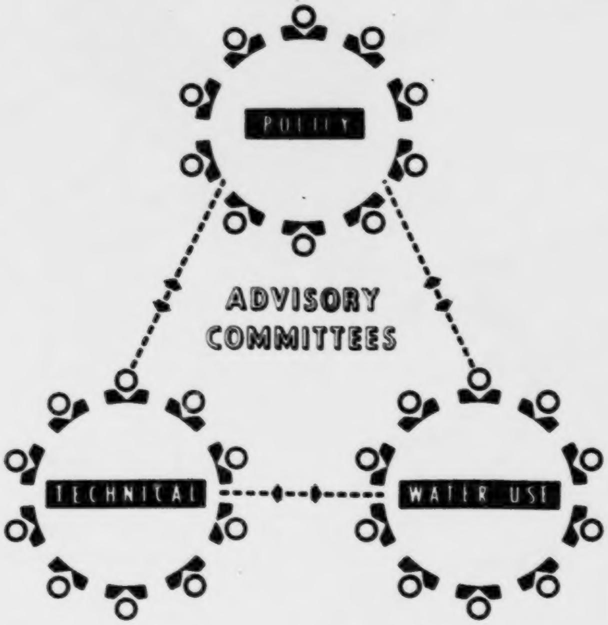

FIGURE 2. - The DECS Advisory Committee structure.

The functions of the PAC include the attainment of a consensus among the agencies on pollution abatement policy and plans and the assurance of full coordination of effort and understanding. The TAC provides for agency appraisal of the technical development of the investigation as well as providing a direct technical assistance in the organization of various projects and providing additional qualified personnel for special phases of the study. The WUAC indicates the needs and the desires of the people of the study area relative to water use with water quality as a criterion.

ACKNOWLEDGEMENT

Any report that deals with complex environmental regional problems such as surround the Delaware Estuary is never successfully completed without the wholehearted cooperation of numerous individuals. It is impossible to list all who gave of their time and energy to contribute so much valuable knowledge and advice. However, the members of the Policy Advisory, Technical Advisory, and Water Use Advisory Committees of the DECS deserve specific mention for proving, in practice, that our system of governmental structure can operate harmoniously with the industrial sector and the general public to produce a meaningful and rational water quality improvement program.

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CHAPTER 2

DESCRIPTION OF STUDY AREA

LOCATION AND BOUNDARIES

The Delaware River is a major watercourse draining a narrow section of northeastern United States. The drainage basin of the Delaware River totals 12,765 square miles covering a five state area: New York, New Jersey, Pennsylvania, Delaware, and a small section of Maryland. The drainage area above Trenton, New Jersey, (6,780 square miles) is commonly referred to as the Central and Upper Regions of the Delaware River Basin. The drainage area below Trenton, New Jersey, is referred to as the Lower Region of the Delaware River Basin. The Lower Region of the basin encompasses the estuary portion of the Delaware River.

The Delaware Estuary is bordered by the states of Pennsylvania and Delaware on the western shore and by the state of New Jersey on the eastern shore. The Delaware Estuary begins at Trenton, New Jersey, and extends 86 miles downstream to Delaware Bay at Liston Point, Delaware. The study area is defined by the service areas of the major water users and waste dischargers (Figure 3). The width of the study area is variable, but is limited to approximately ten miles from the estuary proper and the estuarine reaches of its tributaries. The drainage area of the Delaware River Basin above the lowest point of the study area is approximately 11,330 square miles.

GEOGRAPHY AND TOPOGRAPHY

The headwaters of the Delaware River are in the Appalachian Plateau Province and drain the western slopes of the Catskill Mountains of New York state. Mountain peaks extend to 4000 feet above sea level, though most are in the 2500-3500 feet range.

At Trenton, New Jersey, the Delaware River Bed becomes an outcrop of exposed rock (Fall Line) that dips toward the coast of New Jersey. From this point (head of tide), the Delaware Estuary flows along the eastern side of the Fall Line which divides the Piedmont Province and the Coastal Plain Province. In the Piedmont Province are the less rugged Pocono Mountains with few peaks as high as 2000 feet above sea level. The terrain changes from the Appalacian Plateau Province of heavily wooded hills to broad forested valleys in the Piedmont lowlands.

The area of the Coastal Plain Province is generally composed of moderate rolling hills; however, swampy areas are found in southern

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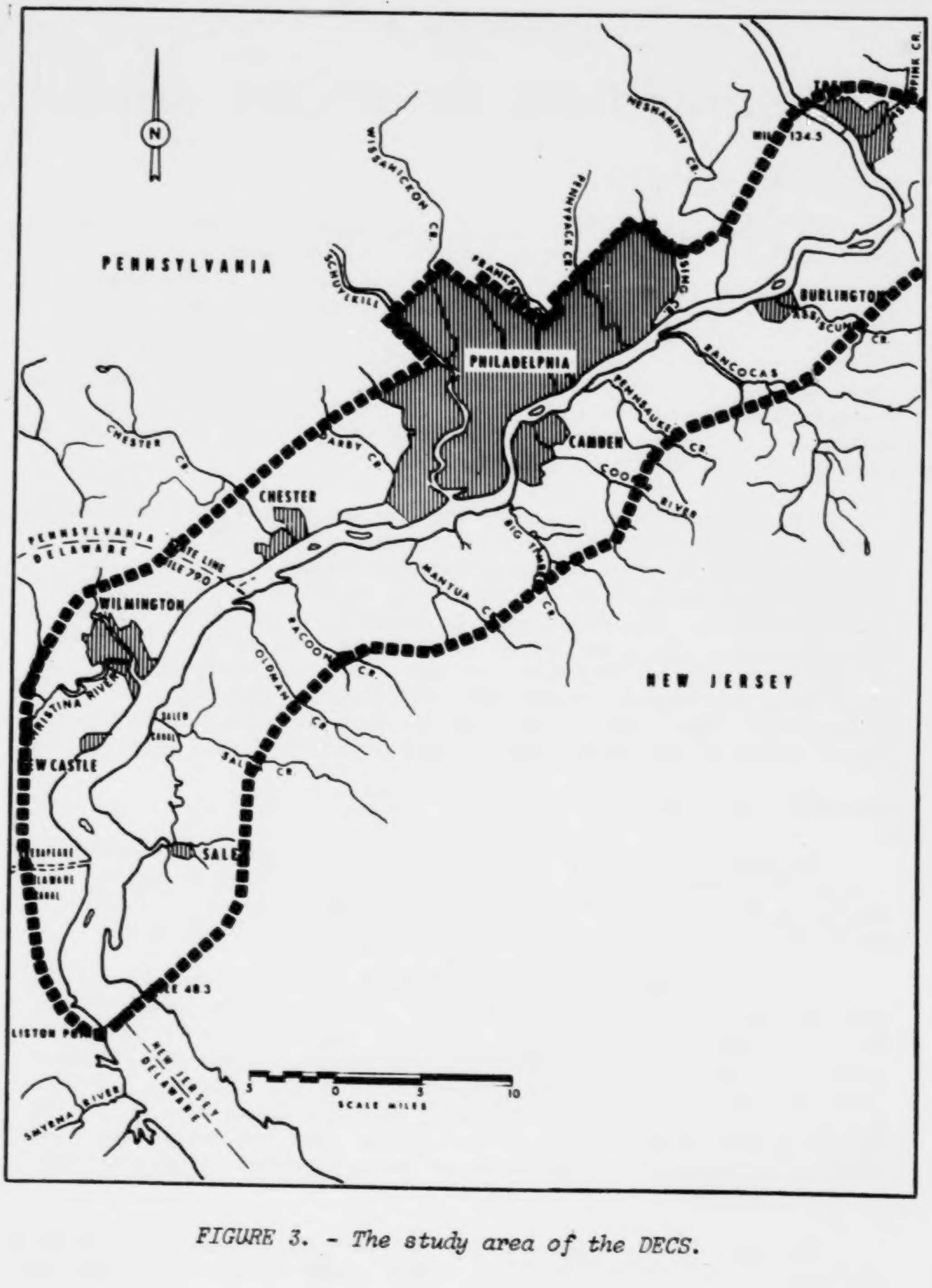
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DARBY CR.
PENNSYLVANIA
DELAWARE
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CHRISTINA RIVER
NEW CASTLE
CHESAPEAKE DELAWARE CANAL
MILE 48.3
SMYRNA RIVER
NEW JERSEY
DELAWARE
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FIGURE 3. - The study area of the DECS.

New Jersey. Basically, the Coastal Plain Province is flat land with sand soils suitable for produce farming. The soils near the Fall Line are more adaptable to farming than those nearer the coast or bay.

GEOLOGY

The Delaware River Basin is mainly composed of two provinces separated by the Fall Line extending from Wilmington, Delaware, to Trenton, New Jersey. The Appalachian Plateau, northwest of the Fall Line, is characterized by glaciated ridges and valleys. The bedrock is consolidated, complex in composition and structure, and generally yields little water to wells. Exposed rock in this part of the basin is coarse hard sandstone that does not normally dissolve or erode. The sparsely populated area is primarily an agricultural and recreational area.

The northwestern boundary of the Coastal Plain Province is an outcrop of bedrock extending above the Fall Line from Trenton, New Jersey, to Wilmington, Delaware. The bedrock nearer the Fall Line is approximately at sea level, dipping to 3500 feet below sea level at Liston Point, Delaware. The bedrock dipping toward the New Jersey Coast is a wedge of unconsolidated deposits of alternating permeable aquifers composed of sand and gravel bounded by aquicludes of clay and silt. These aquifers can generally be developed for ground water supplies almost anywhere in the Coastal Plain Province.

CLIMATE

The Delaware River Basin is in the temperate zone and the climate is generally mild. Sustained periods of very high or low temperatures seldom last more than 3 or 4 days. Mean air temperature ranges from 50°F in the upper basin to 54°F at Wilmington, Delaware.

Precipitation is fairly evenly distributed throughout the year with maximum amounts falling in the summer months. Average annual precipitation in the basin ranges from 42 inches per year in the Wilmington, Delaware area to 60 inches per year for the upper basin.

Heavy snows are not uncommon in the upper basin; however, the Philadelphia area has a mean of only 21 inches. Single storms of 10 inches or more occur about every five years in the Philadelphia area.

The prevailing wind direction for the summer months is from the southwest, while during the winter months north westerly winds are more common. The annual prevailing wind is from the west southwest.

PRINCIPAL COMMUNITIES AND INDUSTRIES

The most heavily populated area of the Delaware River Basin is that area bounding the estuary from Trenton, New Jersey, to Wilmington, Delaware. The basin above Trenton is relatively sparsely populated and undeveloped, except for the lower Lehigh Valley area.

The principal municipal complexes along the main reach of the estuary are: Trenton, N. J., Philadelphia, Pa., Camden, N.J., Chester, Pa., and Wilmington, Delaware. These cities represent one of the most densely populated areas of the country and encompass more than 4,000,000 people.

An extensive complex of industrial plants also lines the Delaware Estuary. Industries distributed on each side of the estuary produce chemicals and allied products, petroleum, primary metals, paper and allied products, processed food and electric power. Table 1 lists the tonnage of various commodities produced in the Trenton, Philadelphia, and Wilmington Metropolitan areas. These figures represent 4.7% of the U. S. total. The most heavily industrialized area is the Camden-Philadelphia-Chester region of the estuary.

TABLE 1

TONS OF COMMODITIES SHIPPED FROM TRENTON, PHILADELPHIA, AND WILMINGTON AREAS (1963)

SIC Code	Commodity Class	Total Tons (thousands)
20	Food and kindred products	4,109
22	Basic textiles	448
23	Apparel, including knit apparel, and other finished textile products	334
26	Pulp, paper, and allied products	1,976
28	Chemicals and allied products	4,314
29	Petroleum and coal products	47,082
30	Rubber and miscellaneous plastics products	696
32	Stone, clay, and glass products	826
33	Primary metal products	4,365
34	Fabricated metal products	1,164
35	Machinery, except electrical	433
36	Electrical machinery and equipment	216
37	Transportation equipment	946
	All other commodity classes	938
TOTAL		67,847

SIC = Standard Industrial Classification

HYDROLOGY

The fresh water inflow to the Delaware Estuary is primarily from the drainage of the Central and Upper Regions of the basin (area above Trenton). The river flows over a series of rock ledges at the Fall Line and enters the estuary at Trenton, New Jersey. The annual average flow at Trenton is 11,680 cubic feet per second (cfs), for the 52 year period of record ending in 1964.

In conjunction with studies of fish passage, monthly distributions of the annual Trenton flows were investigated. The estimated monly distributions of the Trenton mean flow and the one in 25 year low flow are presented in Figure 4.

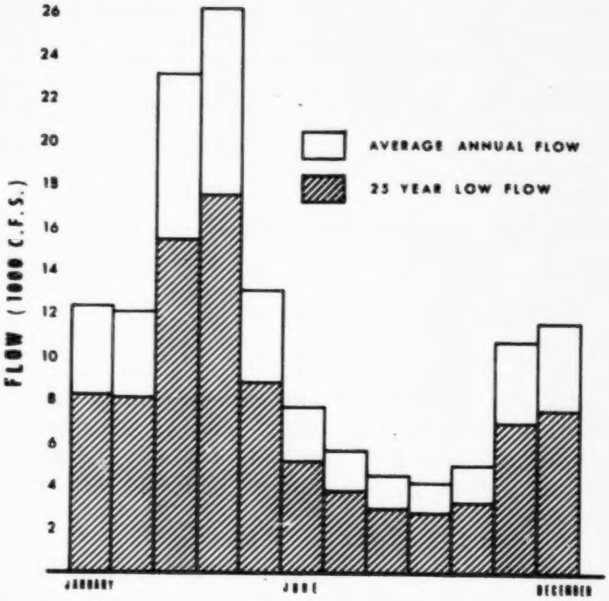


FIGURE 4. - Estimated monthly flow distributions for Delaware River at Trenton, N.J.

In the Lower Region of the basin, additional fresh water inflow to the estuary results from approximately 100 tributaries, most of which are relatively small. The major tributary discharging to the Delaware Estuary is the Schuylkill River with an average annual discharge of 2900 cfs, (1931 to 1964, 33 years). Other gaged tributary flows are presented in Table 2.

TABLE 2

MAJOR GAGED TRIBUTARIES

Stream & Station Location	Estuary Section	Drainage Area (Sq. Miles)	Period of Record	Average Runoff (cfs/sq.mi.)	Average Annual Flow (cfs)
Delaware River (Trenton, N.J.)	1	6780	1912-64	1.76	11,680
Assunpink Creek (Trenton, N.J.)	1	89.4	1923-64	1.33	119
Crosswicks Creek (Extonville, N.J.)	2	83.6	1940-51 1952-64	1.51	126
Neshaminy Creek (Langhorne, Pa.)	5	210	1934-64	1.31	276
North Branch Rancocas Creek (Pemberton, N.J.)	6	111	1921-64	1.52	169
Schuylkill River (Phila., Pa.)	15	1893	1931-64	1.53	2,900
Chester Creek (Chester, Pa.)	18	61.1	1931-64	1.32	80.8
Brandywine Creek (Wilmington, Del.)	21	314	1946-64	1.44	453
Christina River (Cooche Bridge, Del.)	21	20.5	1943-63	1.28	26.2
White Clay Creek (Newark, Del.)	21	87.8	1931-63	1.23	108
Red Clay Creek (Wooddale, Del.)	21	47.0	1943-63	1.34	63.1

The shipping channel of the estuary from Trenton to the Bay ranges from 300-1000 feet in width and 35-45 feet in depth. Associated volumes per 1000 feet of estuary length increase from 15 million cubic feet at Trenton to 250 million cubic feet at the entrance to Delaware Bay.

The Delaware Estuary is responsive primarily to an approximate semi-diurnal lunar tide with a period of about 12 hours and 25 minutes. Other solar and lunar periodic phenomena are also present resulting in a range of period responses in the estuary. Some representative tidal height variations in the Delaware Estuary are presented in Table 3. Figure 5 is an example of current velocities recorded at the Tacony-Palmyra Bridge by a current meter installed by the DECS. Tidal velocities in the estuary average about 1.5 feet per second with maximum velocities of almost 4.0 feet per second.

TABLE 3

TIDAL HEIGHT RANGES

Location	Miles from Delaware Bay Mouth	Tide Range (feet) Mean	Spring
Liston Point, Del.	48.3	5.7	6.4
Philadelphia, Pa.	100.0	5.9	6.2
Trenton, N. J.	132.0	6.8	7.1

Tidal flows in the Delaware Estuary have been investigated at the Delaware Memorial Bridge (mile 68.70). The maximum downstream and upstream flows on August 21, 1957 were approximately 500,000 cfs. In contrast, tidal flows recorded on August 16, 1956 at the Burlington-Bristol Bridge (Mile 117.81) were approximately 60,000-65,000 cfs.

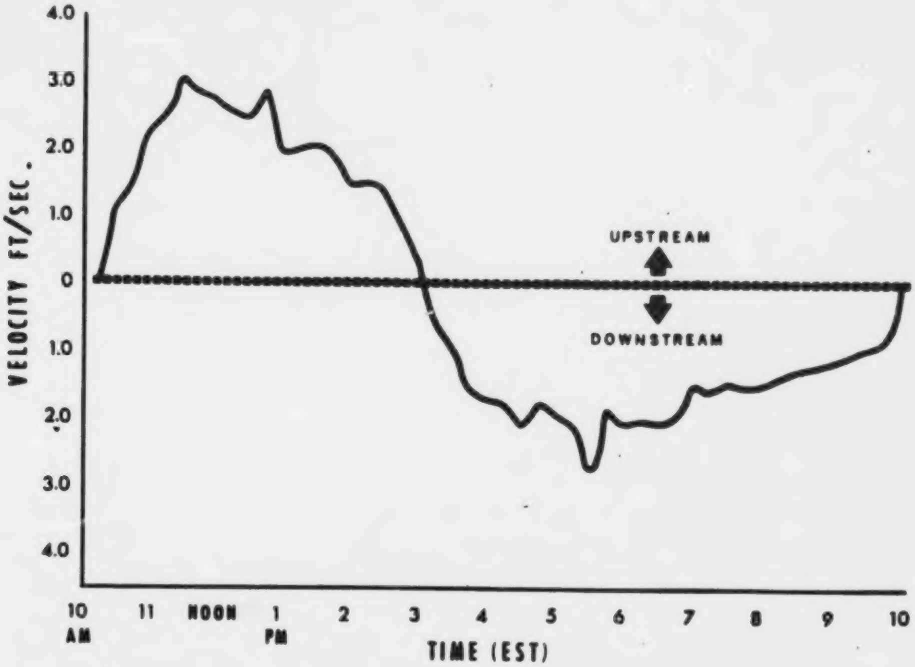


FIGURE 5. - Example of current velocities in the Delaware Estuary at Tacony-Palmyra Bridge, May 11, 1964.

CHAPTER 3

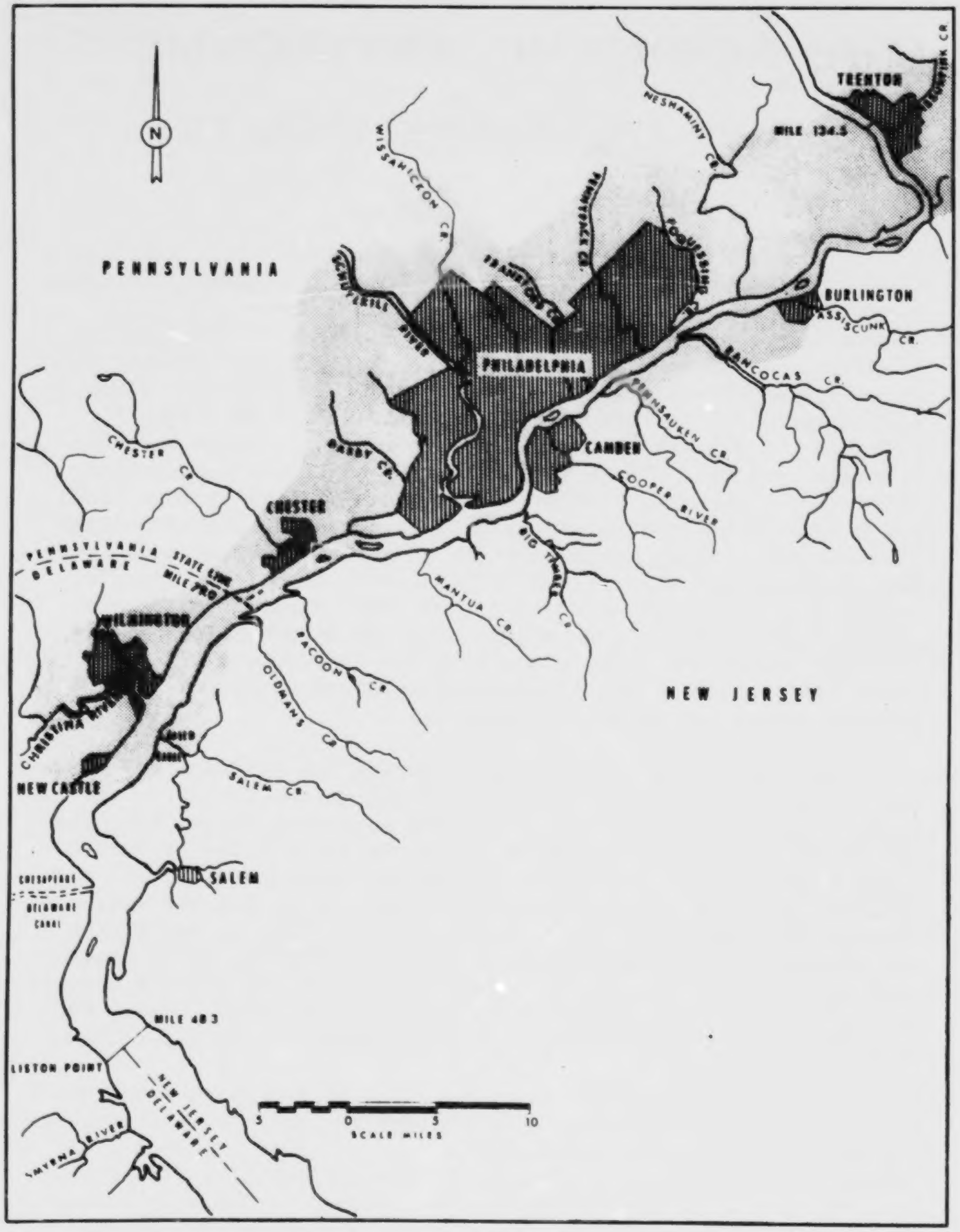
THE ECONOMIC ENVIRONMENT AND ITS WASTE INPUTS

POPULATION

In order to more readily separate urban and rural population in the vicinity of the larger cities along the estuary, urbanized areas have been delineated. These include not only the large central city, but also an urban fringe composed of surrounding incorporated and unincorporated areas. All persons residing in an urbanized area are included in the urban population. Since the criteria for inclusion in the urbanized area are based primarily on density of settlement, it may be expected that the included area will change rather rapidly as larger populations arise in the suburbs. The urbanized areas as finally determined often include only parts of outlying counties and just fractions of townships. These areas have the advantage of being much more homoegeneous than a breakdown of population along, for example, county lines. An urbanized area thus constitutes a contiguous region characterized by a central city and an urban fringe. It probably corresponds most closely to the qualitative ideas of "city' and suburb". The 1960 urbanized areas in the Delaware Estuary region are shown in Figure 6.

Urbanized areas of the type bordering the Delaware are assuming an increasingly important role in the United States. This process has been in evidence since the beginning of the century. The nation as a whole was about 40% urban in 1900 and is over 60% urban today. While the entire nation has grown at about 15% per decade, the urban population has increased about 25% per decade. Between 1950 and 1960, the U. S. overall increase in population was somewhat less than 19%, while the corresponding urban population increased by about 27%. These increments are due, of course, not only to increasing population in some older urban areas, but also to the physical extension of such areas over larger regions.

Specific increases in the population of urbanized areas are given in Figure 7. In the 1950-1960 period, population increments ranged between 24-51%, although the componentsthat make up the urbanized areas showed considerably more variability. The classic pattern of central city decrease and suburban increase is evident. The cities of Philadelphia, Trenton, and Wilmington all decrease slightly over the decade, while the urbanized portions of surrounding counties increase. In one case (Bucks County) this amounts to a spectacular 1100%.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CHESAPEAKE DELAWARE CANAL
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FIGURE 6. - Delaware Estuary urbanized areas in 1960.

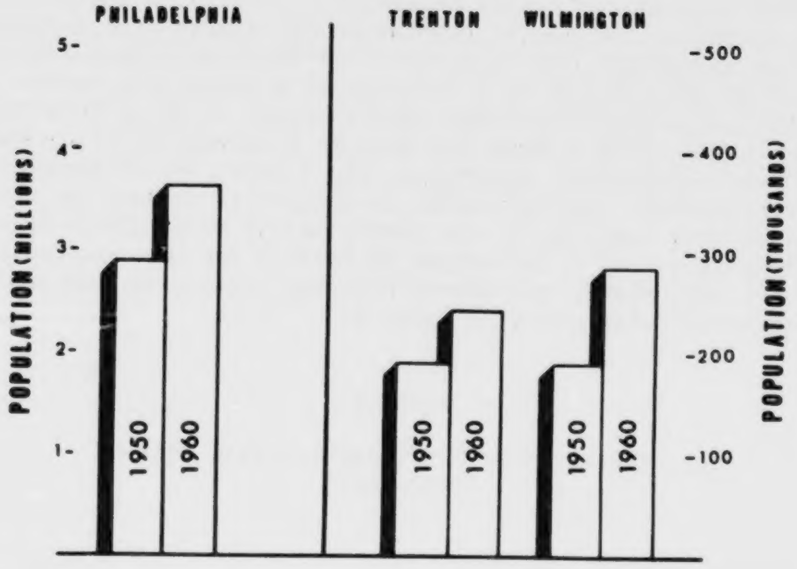

FIGURE 7. - Urbanized area populations, 1950-1960.

In the Delaware Estuary region, the bulk of the population is served by municipal water pollution control plants. Although there are a number of these plants along the estuary of various sizes, over 90% of the discharged municipal load may be attributed to just a few sources. For this reason attention has been focused on these plants in order to determine their present and future effect on the estuary. This means that from the standpoint of water quality the entire DECS urbanized area has been resolved into a number of treatment plants. These plants serve both domestic purposes and industry in the area.

The following municipal water pollution control plants were considered as waste sources in this study:

Wilmington-New Castle Co.
  Wilmington, Delaware

Trenton, N. J.

Camden, N. J.

Chester, Pa.

Philadelphia, Pa. (Northeast)

Philadelphia, Pa. (Southeast)

Philadelphia, Pa. (Southwest)

Central Delaware County
  Authority, Ridley Park, Pa.

Subsequent to the resolution of the urbanized area into these eight waste sources, it became necessary to determine the extent of their service. The served population associated with a plant in 1957 was estimated from inventories of municipal waste facilities. Each of these populations is a function of a particular waste collection system which extended into specific areas at that time. These completely served areas are in turn contained within a **number** of minor civil divisions (townships, etc.) which are of necessity only partly served. The tributary population is defined as the total population residing in the partly-served minor civil divisions. The service structure is presented in Table 4 for each municipal plant. For each plant, the served/tributary ratio was computed. These ratios are also given in Table 4.

TABLE 4

CHARACTERISTICS OF MUNICIPAL SEWERAGE SYSTEMS
1957-1960

Water Pollution Control Plant	Population Tributary	Population Served	Served / Tributary
Trenton, N. J.	215,000	142,000	0.66
Camden, N. J.	118,000	120,000	1.00
Chester, Pa.	81,000	70,000	0.86
Central Delaware County Authority Ridley Park, Pa.	59,000	50,000	0.85
Philadelphia, Pa.			
Northeast	728,000	669,000	0.92
Southeast	761,000	678,000	0.89
Southwest	718,000	731,000	1.00
Wilmington - New Castle Co. Wilmington, Del.	153,000	150,000	0.98
	2,834,000	2,610,000	

EMPLOYMENT, PRODUCTION, INDUSTRY TYPES

The orientation of the Delaware Estuary Study is a very specialized one in that it is directed toward the relationship between industry and water quality. The industries treated here are the so-called "heavy" or "basic" industries. These basic industries tend to be operated on a large scale and usually require individual plant access to the estuary primarily for transportation but also for water supply or waste discharge, although there are exceptions. Specifically, the two classes of industry dealt with are: 1) industries whose waste loading constitutes the major portion of industrial load to the estuary; 2) industries whose surface water use exceeds 1.0 MGD. Obviously, there is a certain amount of overlap between these classes. These industries are denoted by their code numbers as given in the Standard Industrial Classification (SIC) which are identified in Figure 8.

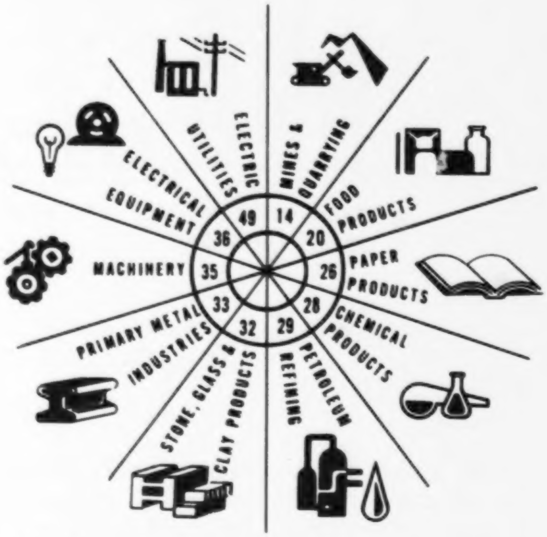
ELECTRIC UTILITIES
49
MINES & QUARRYING
14
FOOD PRODUCTS
20
PAPER PRODUCTS
26
CHEMICAL PRODUCTS
28
PETROLEUM REFINING
29
STONE, GLASS & CLAY PRODUCTS
32
PRIMARY METAL INDUSTRIES
33
MACHINERY
35
ELECTRICAL EQUIPMENT
36

FIGURE 8. - Identification of industries by SIC number.

From the standpoint of water quality some measure of industrial production is most closely related to the waste by-products of operation. Two variables associated with production are: 1) employment, 2) dollar value of output. These variables are used to describe the present (1964) industrial economic structure along the estuary.

Employment is a variable which appears to possess considerable stability over time. For 1964 numerous local sources were consulted in order to determine employment for individual firms. These firms are classified by SIC. In addition, 18 of the firms are designated as substantial waste discharges directly to the estuary, on the basis of the DECS sampling program. The employment data are presented in Figure 9.

The best available measure of production for the industries in the Delaware Estuary region is dollar value of output. It is possible to make statistical estimates of value of output for industries along the estuary. The twofold breakdown into industries primarily discharging waste and those simply using large volumes

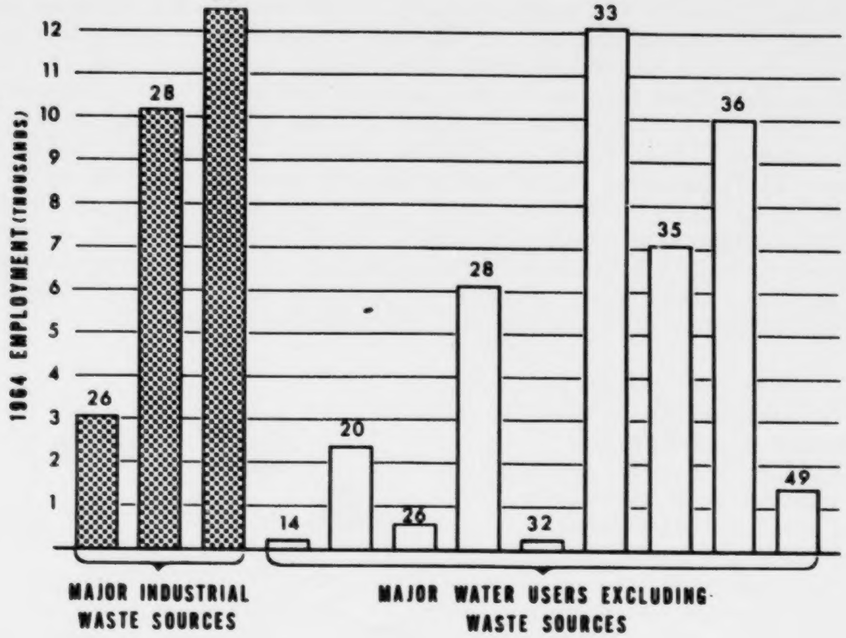

FIGURE 9. - 1964 employment in two-digit SIC's for direct discharging industries.

of water is continued for this parameter very much as it was utilized for employment. Comparison may also be made between value of output and cost of treatment under various treatment policy constraints. The value of output data are presented in Figure 10 for the 19 major industrial waste sources and other industries that use at least 1.0 MGD of estuary water.

PRESENT WASTE LOADS

Waste discharges to the Delaware Estuary are principally municipal and industrial in origin. The municipalities represent the most significant waste sources and generally cover the spectrum of conditions which may exist within a municipal system. Many represent communities which have combined severage collection systems (storm water runoff plus domestic and industrial waste). The large city discharges tend to include significant industrial waste loads.

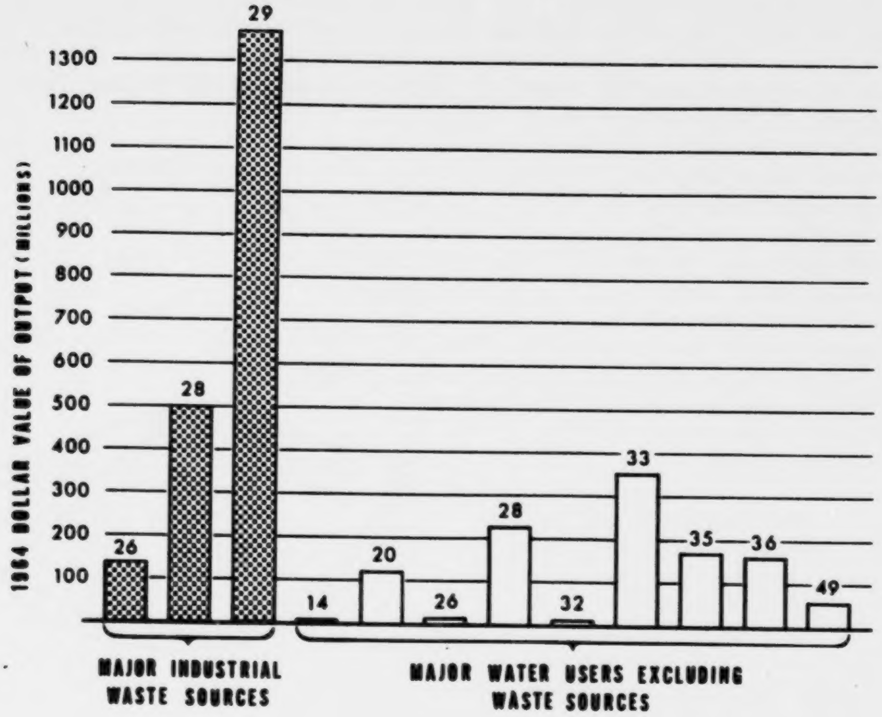

FIGURE 10. - 1964 dollar value of output in two-digit SIC's for direct discharging industries.

Direct industrial effluents contain a variety of complex and unusual organic and inorganic compounds. Also, a broad spectrum of waste concentrations is encountered; this is often due to mixing of waste material with some quantity of cooling water. Numerous other differences due to production processes are found in the industrial effluents.

Two other factors contribute to the overall water quality situation, but both result from the two principal sources indicated above. Storm water overflows from combined sewerage collection systems are basically municipal in origin, and are of importance since they contain untreated diluted municipal waste. Bottom sludge deposits are generally the result of settleable solids discharged from municipal and industrial effluents, as well as storm water overflow and return from dredging spoil areas.

Sampling and analysis programs were undertaken to assess the contribution from each of these sources to the total pollutional loading to the estuary. The programs consisted of the collection of 24-hour composite samples approximately once each month for one year from the major waste sources to the estuary. The results of these programs in terms of carbonaceous oxygen demand load are shown in Figure 11. It will be noted that the waste discharge is approximately 65% municipal and 35% industrial. On the other hand, the municipal discharges appear much less variable in flow and waste concentration than their industrial counterparts.

The geographical distribution of discharged load is presented in Figure 12. The breakdown between municipal and industrial direct discharge can be examined along the length of the estuary.

At certain times of the year in specific areas of the estuary, a nitrogenous oxygen demand from municipal and industrial sources is estimated at about 600,000 #/day.

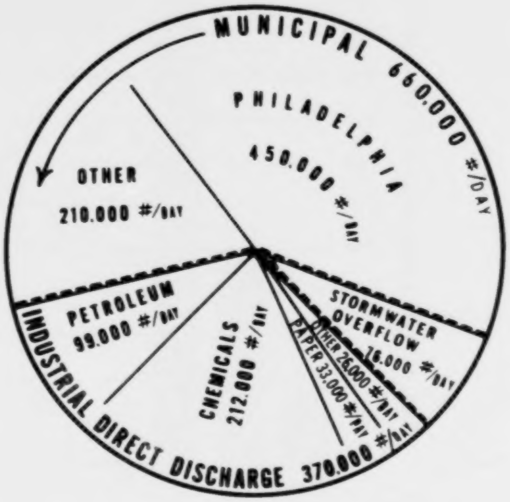

FIGURE 11. - Carbonaceous oxygen demand discharges to the Delaware Estuary - 1964.

An additional oxygen demand is exerted on the estuary by bottom deposits of sludge. This demand is not shown in Figure 11 because deposits are not subject to flow transport phenomena in the same manner as discharged loads. The magnitude of the bottom deposit load is approximately 200,000 #/day. Contributing to the sludge and bottom deposits in the estuary is 740,000 #/day of suspended solids from municipal, industrial and stormwater discharges, of which about 260,000 #/day is estimated settleable.

Aside from the oxygen demand characteristics, several industrial discharges are contributing significant quantities of acidity to the estuary. These discharges average 1,300,000 #/day as $CaCO_3$ during the summer.

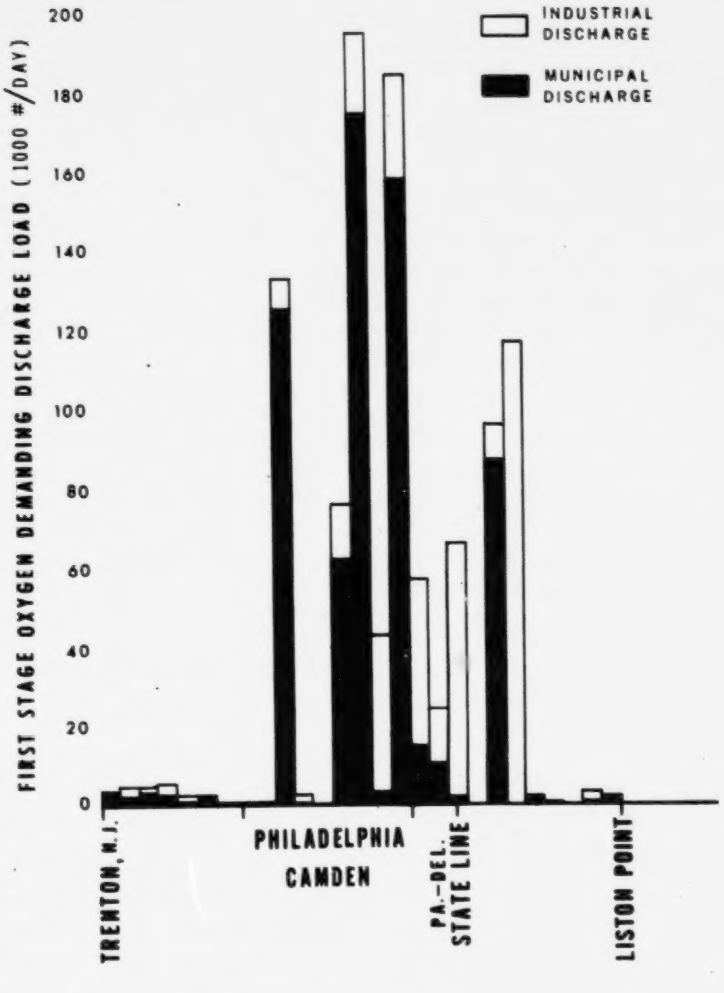

FIGURE 12. - *Municipal and industrial carbonaceous oxygen demand discharges along the Delaware Estuary - 1964.*

The waste loads that have been presented are discharged in the form of effluent flows. The total waste flow for all eight major municipal sources is about 500 MGD; the three Philadelphia water pollution control plants all have flows in the range of 100 - 150 MGD. The industrial effluent flows are so variable that any generalization is very difficult. For all types of industry the mean flows are between 3 - 40 MGD. However, the variability around these means is very great. Industrial effluent flows (including cooling water) as high as 300 MGD have been recorded.

The major portion of the loads are discharged to the estuary after some waste reduction has taken place. Substantial differences may again be found among waste sources. On the one hand, the municipal treatment processes are relatively well defined. All municipal sources along the estuary possess at least primary treatment (about 30-39% removal of oxygen demanding load). The industrial situation is not as well defined. The process that constitutes "reduction" may cover in-plant modification, separation of cooling and process water, as well as a number of techniques designed to reduce wastes peculiar to a given industry. All these processes may be subsumed under the category of waste reduction. Using this definition, industrial waste reduction along the estuary ranges from none (zero percent removal) to high secondary-tertiary (90-98% removal). Recognizing the highly variable nature of treatment, it is still possible to evaluate an effective system percent removal of raw waste for the sources along the estuary taken as a whole. At present (1964) this estimated system percent removal is about 50%.

The stormwater overflow discharges were found to possess a distinctly individual character. In terms of absolute magnitude, the load does not appear large. However, the input to the estuary is through a series of impulses approximately random in both magnitude and interval of recurrence. Hence it may be responsible for some oxygen depletion for short periods of time. The nature of these discharges is depicted in Figure 13. The storm water discharge contains high concentrations of coliform bacteria that are also discharged on an intermittent basis. Another more important factor, which is not readily quantified, is the esthetic effect attributable to these overflows. The occurrence of overflows results in the discharge of solids, floating material, and miscellaneous flotsam which are normally trapped by the treatment plant. Although this material may not constitute a large source of oxygen demanding pollution, its presence is quite objectionable and certainly may be termed pollution by the general public.

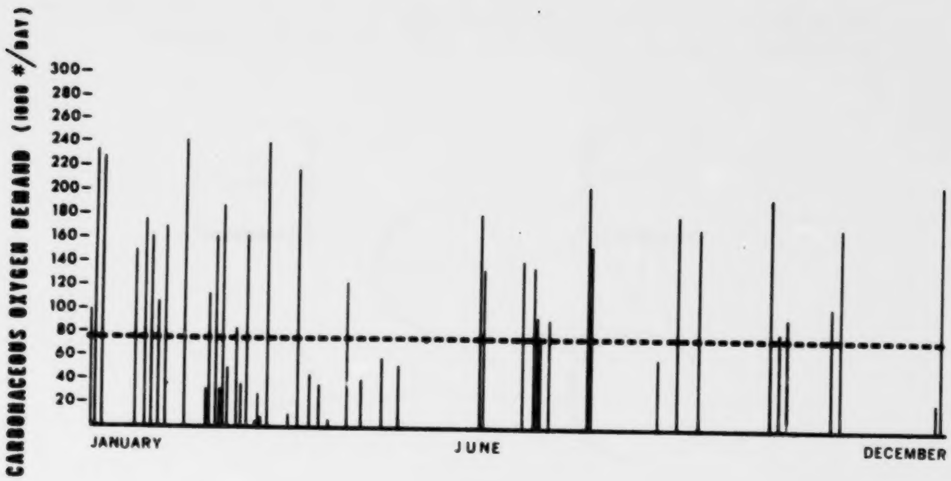

FIGURE 13. - Simulated stormwater overflow distribution over time. Dashed line represents mean load over year.

ECONOMIC TRENDS & OUTLOOKS

This section presents the components of economic growth affecting water quality in the Delaware Estuary region. Trends are projected on the assumption that there will be no major inflationary trends or severe economic depressions, and that the economy will continue to grow roughly at the same rate as it has in the past. For concise presentation, only a few of the projections that are detailed in Part Two are given; these are Municipal Projection 1 (Production), and Industrial Projection 2 (Employment). They constitute an approximately "medium" condition.

In a highly integrated metropolitan economy such as surrounds the Delaware Estuary, there is a considerable amount of interdependence between economic components. A simple diagram showing functional dependence among projected variables is given in Figure 14. Change in part of the system affects other portions. The regional economy is closely bound together, and advances as a whole. The projections cover only a fraction of this economy, specifically the part closely connected with water quality in the estuary. Thus, for example, the population considered is that which is tributary to eight **municipal** water pollution control plants.

Similarly, production and employment are projected only for major industries discharging directly to the estuary.

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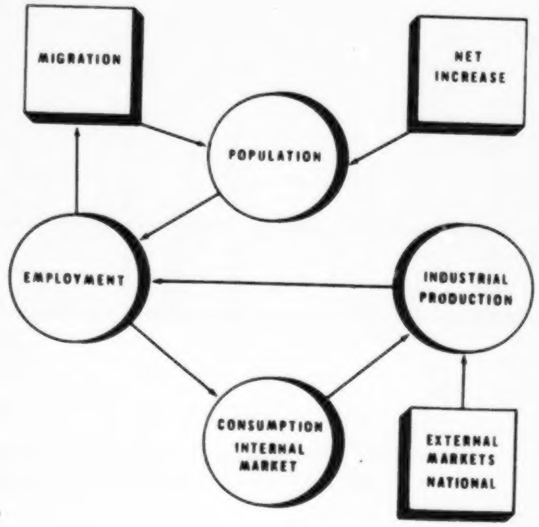

MIGRATION
NET INCREASE
POPULATION
EMPLOYMENT
INDUSTRIAL PRODUCTION
CONSUMPTION INTERNAL MARKET
EXTERNAL MARKETS NATIONAL

FIGURE 14. - Economic functional dependence in the Delaware Estuary region.

The population projection is shown in Figure 15. These values are the result of considering natural increase (birth minus death rates) plus migration in and out of the region.

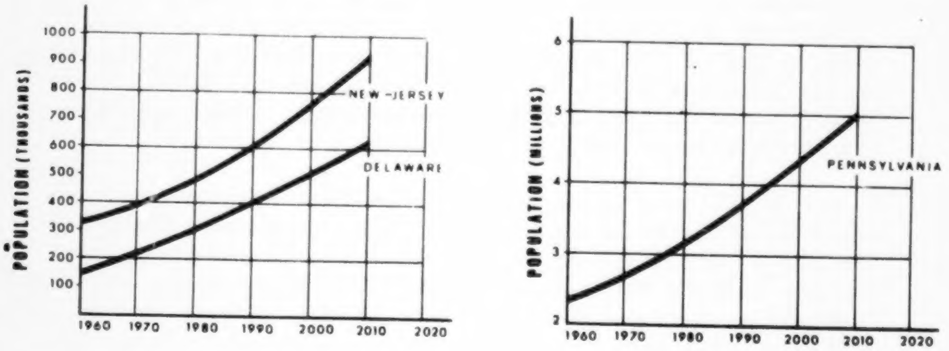


FIGURE 15. - Estimated population tributary to major water pollution control plants along the Delaware Estuary, 1960-2010.

Population is an extremely fundamental variable, but it is partly dependent on the general economic life (e.g. employment opportunities) of the region. The population forms the pool from which are drawn employees and consumers for the major industries, as well as for the tremendous metropolitan service structure. In this sense it may be regarded as an economic driving force. The population in the three-state area considered in Figure 15 is estimated to increase by about 30% between 1960 and 1975, and by about 135% between 1960 and 2010

The employment projection for directly discharging industries is given in Figure 16. These values are dependent on industrial activity in the region, and simultaneously constitute part of the local market on which industries depend. The total employment is estimated to increase about 25% between 1964 and 1975, and approximately 140% between 1964 and 2010.

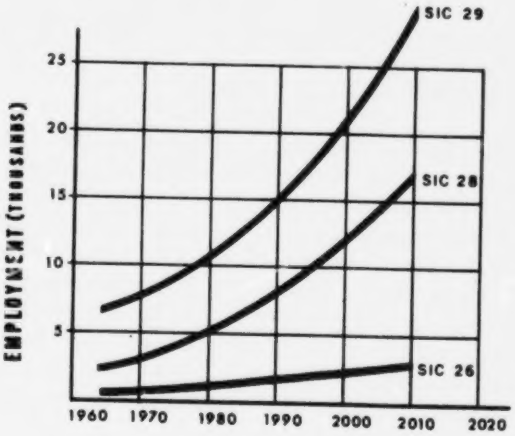


FIGURE 16. - Estimated Employment in major direct discharging industries along the Delaware Estuary, 1964-2010.

The productivity of directly discharging industries can be measured by the dollar value of output and is projected in Figure 17. The dollar inflow due to this activity is considerable; in 1964 it is estimated at some two billion dollars. This inflow is derived from both national and regional markets, and is partly disbursed within the region in various forms. The total productivity as measured is estimated to increase by about 45% between 1964 and 1975, and by 395% between 1964 and 2010.

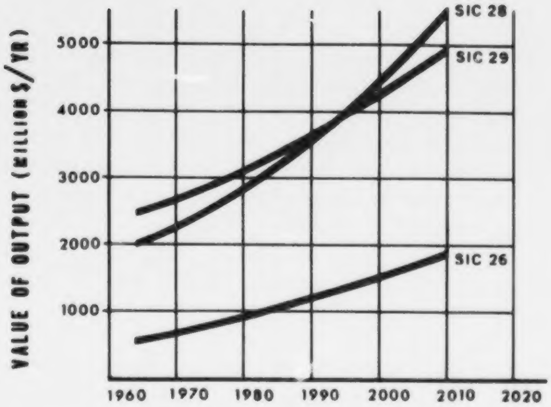


FIGURE 17. - Estimated value of output for major direct discharging industries along the Delaware Estuary, 1964-2010.

FUTURE WASTE LOADS BEFORE REDUCTION

This section presents projected waste loads to the Delaware Estuary, and compares them to present (1964) conditions. The forecasts are selected from a series of projections and represent a "medium" condition -- neither the lowest nor the highest obtained. The municipal and industrial loads are separately forecast and the resultant loads combined to give the total estimated waste load. The results are presented in Figure 18 in the form of oxygen demanding load before reduction. The 1964 values are those obtained as part of the DECS sampling program.

The future municipal loads are principally caused by the discharges from eight waste treatment plants along the estuary. The municipal population projection provides the basis for estimating the increased load over time. Certain municipal trends are assumed to exist. For example, the service area of the plants is assumed to expand over the years; in addition, it is postulated that at irregular, but distinct intervals in time, new political subdivions will be added to the municipalities. Such considerations lead to a dynamic concept of the ratio of served to total population.

Consideration is also given to two effects which cause an increase per capita domestic load over time. One of these is the growing use of domestic garbage disposal units, and the second is the trend toward more utilization of significant water-using home appliances such as dishwashers and automatic washers by the general public.

Finally, account is taken of the increasing numbers of municipally-served industries. The load from these is also reflected in the municipal projections as a factor acting to increase per capita daily load.

It will be noted from Figure 18 that the municipal portion of the total load before reduction is estimated to increase from about 65% in 1964 to about 70% in 1975, and then drops to about 60% by 2010. An index for municipal load based on 1964 = 100 yields 232 in 1975 and 497 in 2010.

The future industrial loads were obtained from an analysis using Standard

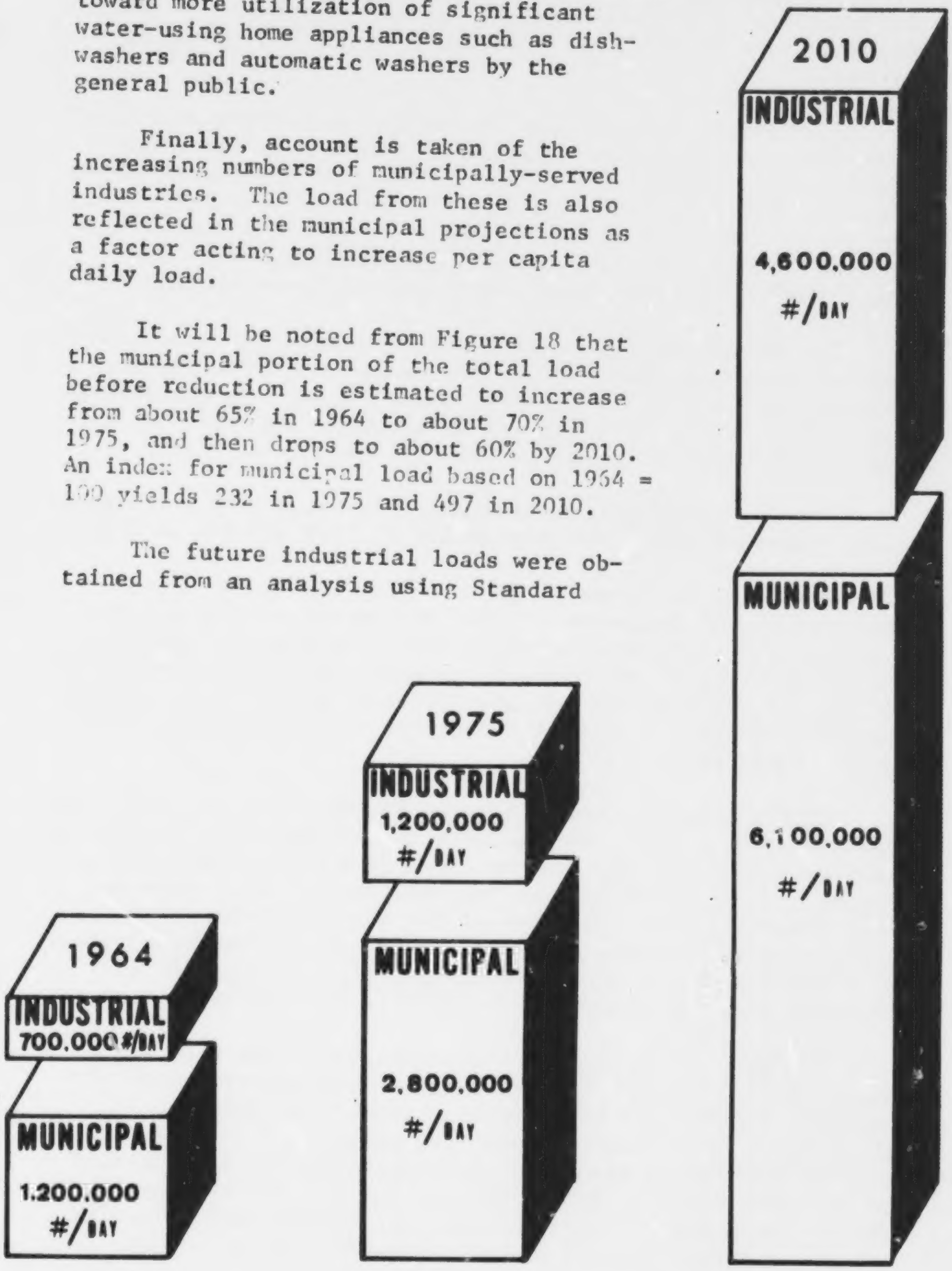


FIGURE 18. - Projected waste loads before reduction - carbonaceous oxygen demand (#/day).

Industrial Classifications (SIC's) represented by industries along the estuary in the major groups 26 (paper manufacturing), 28 (chemical industries), and 29 (petroleum refining). These major sources of load were determined by the DECS sampling program.

Statistical estimates of production in dollars/year have been made for industries discharging directly to the estuary. The future production for direct discharging industries in the SIC's is then projected over time. A further consideration is the change over time of waste load per unit of production due to many factors affecting trends in technology. From this trend the future waste load before treatment was derived.

The results in Figure 18 indicate that of the total load before reduction, about 35% is due to industry directly discharging to the estuary in 1964, about 30% in 1975 and greater than 40% in 2010. An index for industrial load based on 1964 = 100 gives values of 187 in 1975 and 685 in 2010.

For the combined municipal and industrial loads, a similar index based on 1964 = 100 yields 216 in 1975 and 564 in 2010.

The loads in Figure 18 are directly related to those employed in the estimates of cost to improve estuary water quality. However, the nature of this relationship must be viewed in terms of the economic interaction between industrial production revenues and the construction cost of waste treatment facilities. A systems diagram of this interaction is shown in Figure 19.

Cost information was requested by DECS from the individual waste sources. These data reflect the potential of increasing load over time, as well as the economic interactions of Figure 19. When all factors are considered, the responses fall generally into two classes: 1) the industries that anticipate no economic change in their net load removal costs; 2) a few industries and all municipalities that expect an increase in their net costs to maintain 1964 waste discharges.

For most of the industries considered, cost data are based on 1964 loads, although they reflect consideration of possible future load increments. However, an increase in these loads over time is projected, which implies greater cost to maintain a specified discharge than may be indicated by the cost curves. The difference in cost can be accounted for by reduction of waste through plant modification, and by revenue obtained through product recovery. It is assumed that these two considerations will offset the cost of treating larger future loads, at least through 1975. Estuary industries are in the process of carrying out just such programs at present. In an economic sense, therefore, the "effective raw loads" for most industries should be regarded as the 1964 values in Figure 18 since the net cost of a specific discharge remains constant over time.

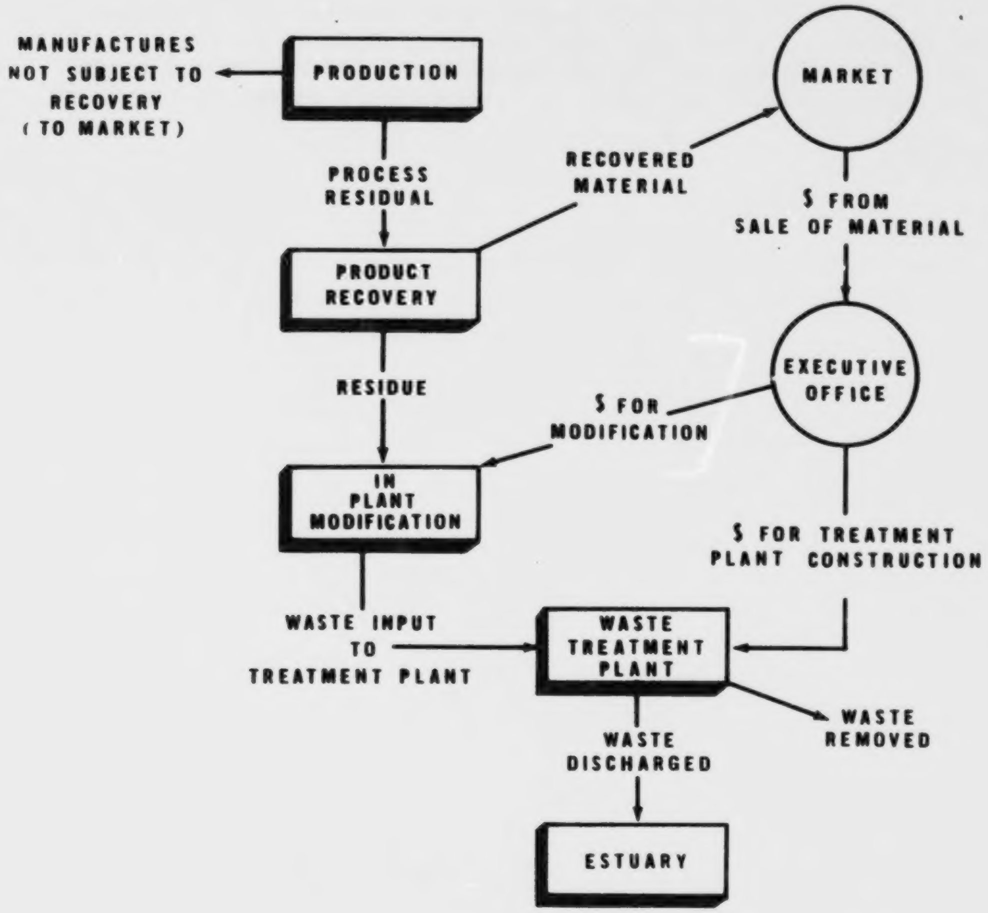

MANUFACTURES NOT SUBJECT TO RECOVERY (TO MARKET)
PRODUCTION
MARKET
PROCESS RESIDUAL
RECOVERED MATERIAL
$ FROM SALE OF MATERIAL
PRODUCT RECOVERY
RESIDUE
EXECUTIVE OFFICE
$ FOR MODIFICATION
IN PLANT MODIFICATION
$ FOR TREATMENT PLANT CONSTRUCTION
WASTE INPUT TO TREATMENT PLANT
WASTE TREATMENT PLANT
WASTE REMOVED
WASTE DISCHARGED
ESTUARY

FIGURE 19. - Systems diagram of industrial production - waste discharge process.

For a few industries and for all municipalities, a different situation prevails. These sources have supplied cost data that indicate consideration of larger future loads.

The industries indicate a cost increase due to 1975 loads, a cost which cannot be completely offset according to their plans. Therefore, the "effective raw loads" for these sources are the 1975 values of Figure 18; these loads might be somewhat less, depending on the efficiency of in-plant waste reduction programs. The economic constraint states that any further treatment costs must be offset by product recovery credits.

The municipalities of course do not possess the mechanism in Figure 19. Their cost data are based directly on larger anticipated future loads; consequently the "effective raw loads" for municipalities are taken to be the future values in Figure 18.

CHAPTER 4

WATER QUALITY

PRESENT WATER QUALITY

The present (1964) water quality of the Delaware Estuary was determined from a series of weekly sampling runs, made by the DECS staff, together with data collected by the U. S. Geological Survey, the city of Philadelphia, and the state of Delaware. A number of water quality parameters were investigated, including water temperature, dissolved oxygen, nitrogen constituents, alkalinity and coliform bacteria.

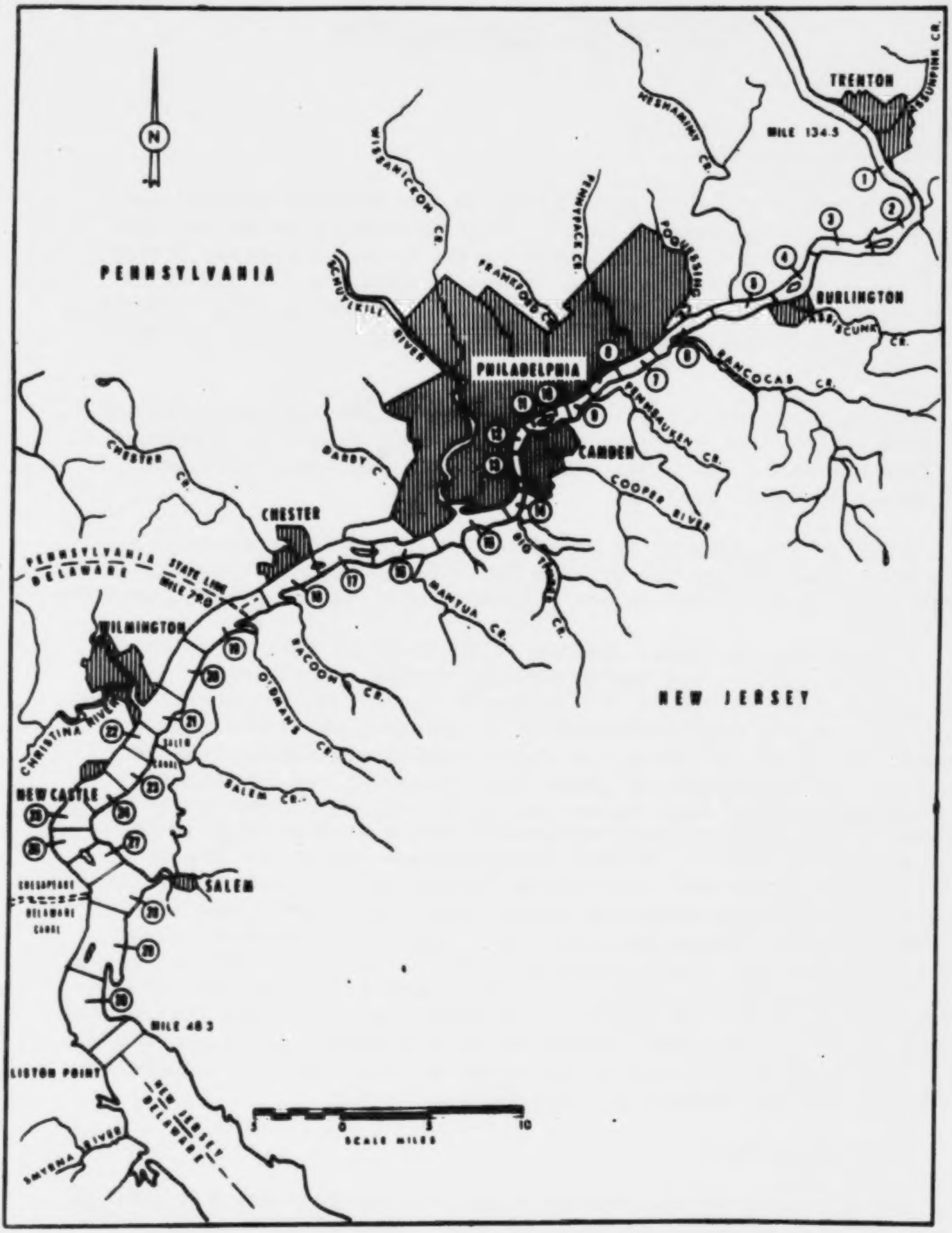
On the basis of these data, a summary of present water quality is given below. For purposes of this summary, dissolved oxygen, coliform bacteria, chlorides, and alkalinity are used as primary indicators of water quality.

A map of the estuary is presented in Figure 20. The sections into which the estuary was divided for various computational procedures are shown to aid in the orientation of the sampling locations.

In general, the water quality at the head of tide at Trenton, N. J., is excellent, but begins to deteriorate immediately. From Torresdale, Pa., Section 7, to below the Pennsylvania-Delaware state line, Section 19, the deterioration is extreme; as a result of waste discharges, dissolved oxygen is almost completely depleted in some locations and production of gases from anaerobic organic deposits is sometimes noted. The concentration of coliform bacteria resulting primarily from unchlorinated municipal wastes is very high in the same stretch of river. Surface discoloration due to the release of oil from vessels and surrounding refineries is a common occurrence from Philadelphia to below the state line. Acid conditions due to industrial waste discharges have been observed for several miles above and below the Pennsylvania-Delaware state line. The net result is a polluted waterway which depresses aesthetic values and reduces recreational, sport and commercial fishing, and decreases its utility for municipal water uses. Intrusion of salt water, while not caused by pollution, also imposes a limitation on municipal and industrial water uses during periods of extended low flows.

Dissolved Oxygen

Table 5 presents the average dissolved oxygen concentration for several of the sampling stations for four three-month periods in 1964.


N
PENNSYLVANIA
NEW JERSEY
TRENTON
ASSUNPINK CR.
MILE 134.5
NESHAMINY CR.
WISSAHICKON CR.
PENNYPACK CR.
FRANKFORD CR.
POQUESSING
SCHUYLKILL RIVER
PHILADELPHIA
BURLINGTON
ASSISCUNK CR.
RANCOCAS CR.
PENNSAUKEN CR.
CAMDEN
COOPER RIVER
DARBY C.
CHESTER CR.
CHESTER
BIG TIMBER CR.
MANTUA CR.
PENNSYLVANIA STATE LINE DELAWARE
MILE 79.0
WILMINGTON
RACOON CR.
OLDMANS CR.
CHRISTINA RIVER
SALEM CANAL
SALEM CR.
NEW CASTLE
SALEM
CHESAPEAKE DELAWARE CANAL
MILE 48.3
LISTON POINT
NEW JERSEY
DELAWARE
SMYRNA RIVER
5
0
5
10
SCALE MILES
1
2
3
4
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8
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FIGURE 20. - Map of Delaware Estuary showing section breakdown.

TABLE 5

DISSOLVED OXYGEN DATA FOR 1964

Station Name Approximate Location	Ave. Dissolved Oxygen (mg/1) Jan-Mar	 Apr-June	 July-Sept	 Oct-Dec
Fieldsboro, N.J. Section 2	12.2	9.6	6.7	9.5
Burlington, N.J. Section 4	12.0	8.3	5.2	8.2
Torresdale, Pa. Section 6	12.1	8.3	6.4	7.8
Tacony-Palmyra Br. Section 8	11.9	7.7	4.7	6.6
Ben. Franklin Br. Section 12	10.5	5.5	1.2	2.9
Phila. Navy Yard Section 15	9.7	5.2	0.7	1.6
Eddystone, Pa. Section 17	8.7	5.1	1.0	1.8
Marcus Hook, Pa. Section 19	9.0	3.4	1.7	3.2
Del. Mem. Br. Section 22	9.8	4.6	4.5	7.4
Reedy I., Del. Section 29	11.8	7.7	7.2	9.8

The most critical period is the July-September summer months during which the average dissolved oxygen was below 4.0 mg/1 from about Section 8 to Section 20 and below 3.0 mg/1 between Section 10 and Section 19. A plot of the summer dissolved oxygen level is given in Figure 21. On any given day, the dissolved oxygen can be considerably below these averages: the continuous water quality monitor records of the U.S.G.S. indicate that complete exhaustion of the oxygen often results during this period in the critical sections. The DO variability both within a day and throughout the year is due to many factors including tidal and wind phenomena which can cause short term changes of up to 1.5-2.0 mg/l and the seasonal variation of water temperature. This latter variation is most important and comparison of the seasonal averages in Table 5 show differences of up to 9.0 mg/l between winter and summer.

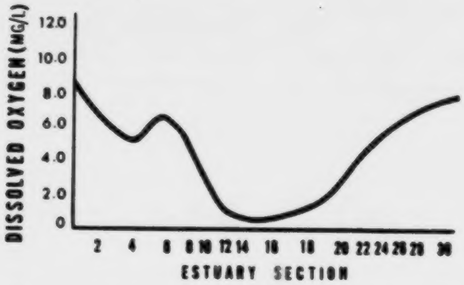

FIGURE 21. - Profile of average summer (June-August, 1964) dissolved oxygen (mg/l).

Coliform Bacteria

Geometric mean coliform bacteria counts for the summer period are given in Figure 22. The coliform group is used as a general bacterial indicator and is composed of usually nonpathogenic organisms always found in sewage. Coliform bacteria are also found in soil and vegetation, so that the presence of this group does not necessarily indicate that disease producing organisms are present, but that they may be. High counts are generally found in the same 40 mile stretch from Torresdale to the Delaware Memorial Bridge in which the major DO problem exists.

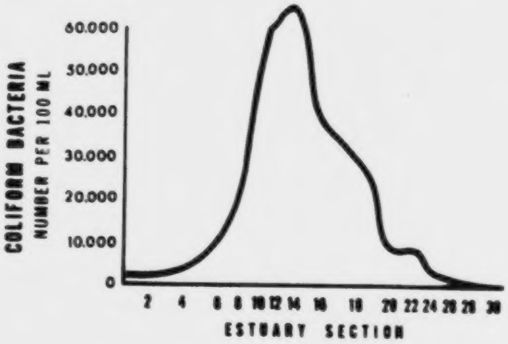

FIGURE 22. - Profile of geometric mean summer (June-August, 1964) coliform bacteria (#/100 ml).

Alkalinity

Figure 23 shows the average summer alkalinity observed in the river compared to the estimated normal alkalinity. The discrepancy is due to the utilization of the alkalinity by acid discharges. The deficit is especially critical in the area above and below the Delaware Memorial Bridge where on any given day the alkalinity may be as low as 9 or 10 mg/l.

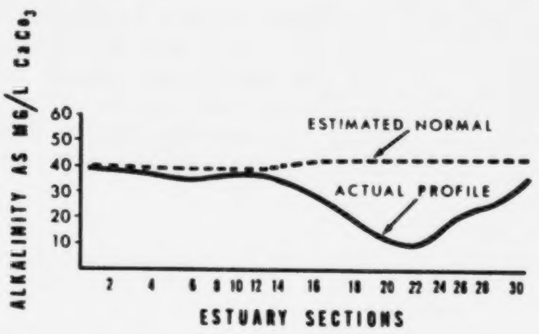

FIGURE 23. - *Profile of average summer (June-August, 1964) alkalinity (mg/l).*

Chlorides

The curve shown in Figure 24 represents the maximum chloride intrusion in 1964. Salt water intrusion which limits the use of water in the portion of the estuary below Philadelphia is a serious problem whenever low flow conditions persist for relatively long periods of time.

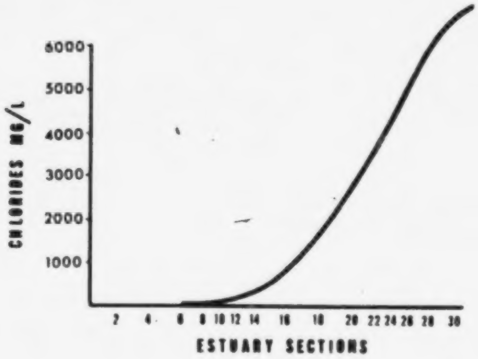

FIGURE 24. - *Maximum chloride (mg/l) intrusion during 1964.*

MATHEMATICAL ANALYSIS OF CAUSE & EFFECT RELATIONSHIPS

The need for a rigorous mathematical representation of the cause and effect relationships relevant to water quality was realized early in the Study. This representation is necessary in order to give a sound basis to the techniques for effective management of the estuary. The formulation of this representation requires a knowledge of the physical characteristics of the estuary as well as the biological and chemical transformations involved.

The basic system for dissolved oxygen is shown in Figure 25, and is composed of two subsystems: 1.) the biochemical oxygen demand (BOD) system, and 2.) the dissolved oxygen system. These systems were mathematically modeled for the Delaware Estuary. The models were modified to permit the description of other water quality parameters such as chlorides, pH, alkalinity, and the nitrogen cycle.

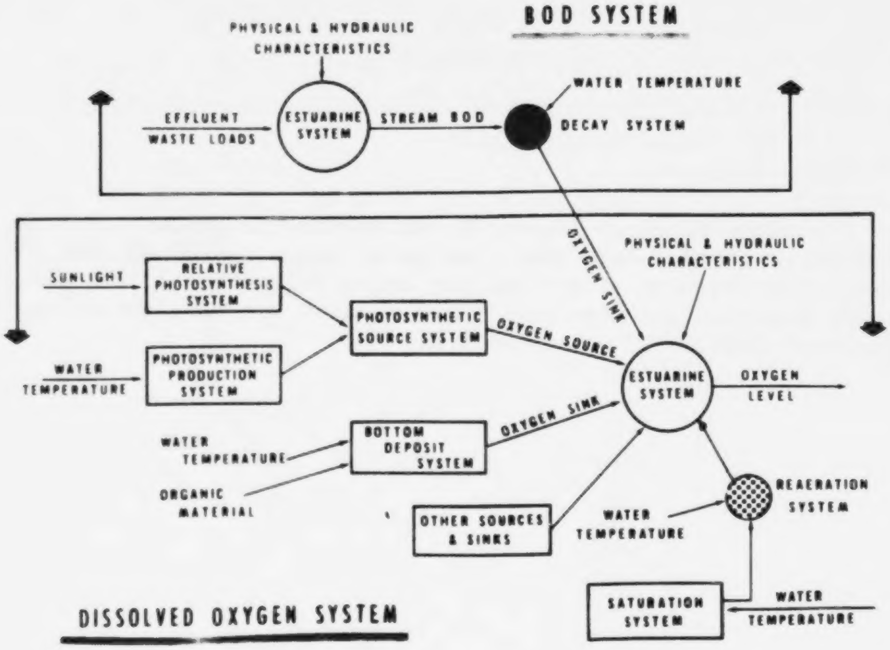
BOD SYSTEM
PHYSICAL & HYDRAULIC CHARACTERISTICS
EFFLUENT
WASTE LOADS
ESTUARINE SYSTEM
STREAM BOD
WATER TEMPERATURE
DECAY SYSTEM
OXYGEN SINK
PHYSICAL & HYDRAULIC CHARACTERISTICS
SUNLIGHT
RELATIVE PHOTOSYNTHESIS SYSTEM
PHOTOSYNTHETIC SOURCE SYSTEM
OXYGEN SOURCE
WATER TEMPERATURE
PHOTOSYNTHETIC PRODUCTION SYSTEM
ESTUARINE SYSTEM
OXYGEN LEVEL
OXYGEN SINK
WATER TEMPERATURE
BOTTOM DEPOSIT SYSTEM
ORGANIC MATERIAL
REAERATION SYSTEM
OTHER SOURCES & SINKS
WATER TEMPERATURE
SATURATION SYSTEM
WATER TEMPERATURE
DISSOLVED OXYGEN SYSTEM

FIGURE 25. - Dissolved oxygen system.

In order to mathematically represent the estuary, it was divided into 30 sections (Fig. 20) with the lengths representing a compromise between accuracy and computational efficiency. For each of these sections a mass balance equation was written for the biochemical oxygen demand system. A similar equation was written for the dissolved oxygen system. This resulted in two linear differential equations based on the physical, hydrological and biochemical characteristics. Once all thirty sections were modeled, the result was two systems of thirty simultaneous equations each.

If the simplifying assumption is made that the equations do not vary with time, matrix manipulation techniques can be utilized to obtain a set of transfer functions from the coefficients of the equations. The set of transfer relationships details the transformation from a waste load input in any section to the stream quality output in any other section; for example, from effluent waste load to stream BOD, from stream BOD to dissolved oxygen, and directly from effluent waste load to dissolved oxygen. Numerous sets of these transfer functions were computed for various fresh water inflow conditions, tidal diffusion constants, decay rates, and reaeration rates. Figure 26 presents a typical cause and effect relationship; the increase in stream BOD caused by a steady load of 100,000# of BOD discharged per day into Section 10, during low flow summer conditions. Figure 27 shows the effect on dissolved oxygen resulting from this same input.

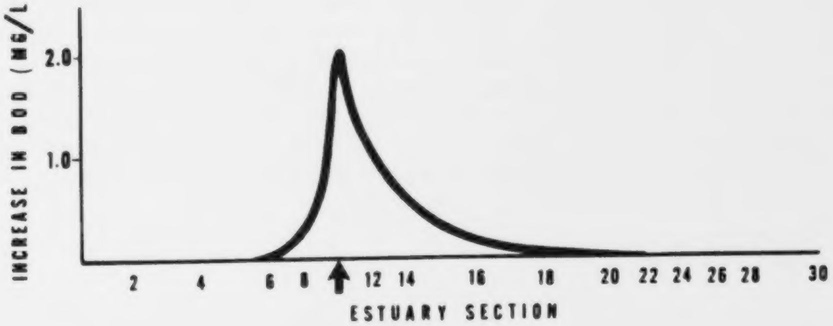

FIGURE 26. - Effect on stream BOD of 100,000# of oxygen demand discharged into section 10.

It is a property of these types of equations that several solutions can be added to one another. Therefore, if the total effect at any section is desired, it can be found by summing each of the effects in that section caused by inputs anywhere in the estuary.

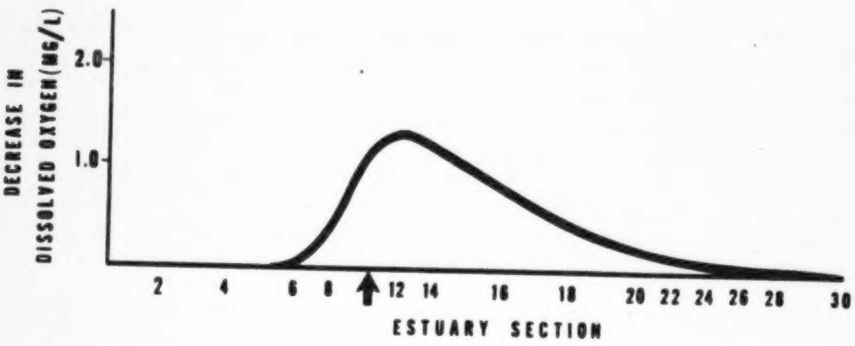

FIGURE 27. - Effect on DO of 100,000# of oxygen demand discharged into section 10.

If the problem is of a time varying nature, the equations can be solved using analog or digital computers. The time varying solution allows the verification of the model with past data which do not usually conform to steady state conditions. Numerous comparisons were made between the model results and the prototype and all indicate that the model can be used with a sufficient degree of accuracy. Once the verifications have been made, thus setting the parameters in the equations more accurately, simulations can be made of countless hypothetical situations such as the effect of flow regulation, effluent load regulation, and the additions of supplemental oxygen against a background of changing temperature and natural flows. As an example, Figure 28 shows a typical dissolved oxygen profile at Section 13 as it appears under normal flows and loads over the year and again as it appears under the same flow but with 95% of the major carbonaceous oxygen demanding effluents removed.

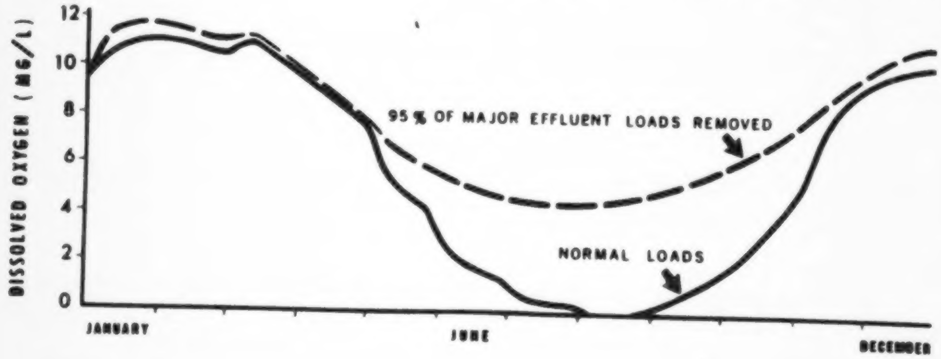

FIGURE 28. - Effect on DO in section 13 of removal of carbonaceous oxygen demand.

Figure 29 shows the effect of an intense short duration discharge such as an accidental spill. The input in this example is 200,000# of BOD discharged at one time into Section 15.

There is an important need to model other water quality variables as well as dissolved oxygen, and fortunately, the models developed for BOD and DO can readily be modified for other uses. If only those parts of the system used for BOD (Figure 25) are solved, and if the proper decay rates and variable names are substituted, the cause and effect relationships for such non-conservative variables as bacteria concentrations can be obtained. These are, in form, exactly the same as the BOD system.

Simplifying further, if the decay mechanism is eliminated in the BOD system, the model is suitable for use with such conservative variables as alkalinity-pH, and chlorides. The simplified system for chlorides is shown in Figure 30.

Verification of the model using past chloride records is very useful since there is but one source, at the bay, and only the physical and hydrological parameters are present to be "tuned". Since these parameters are the same for all quality variables, they can then be used in simulations other than salinity.

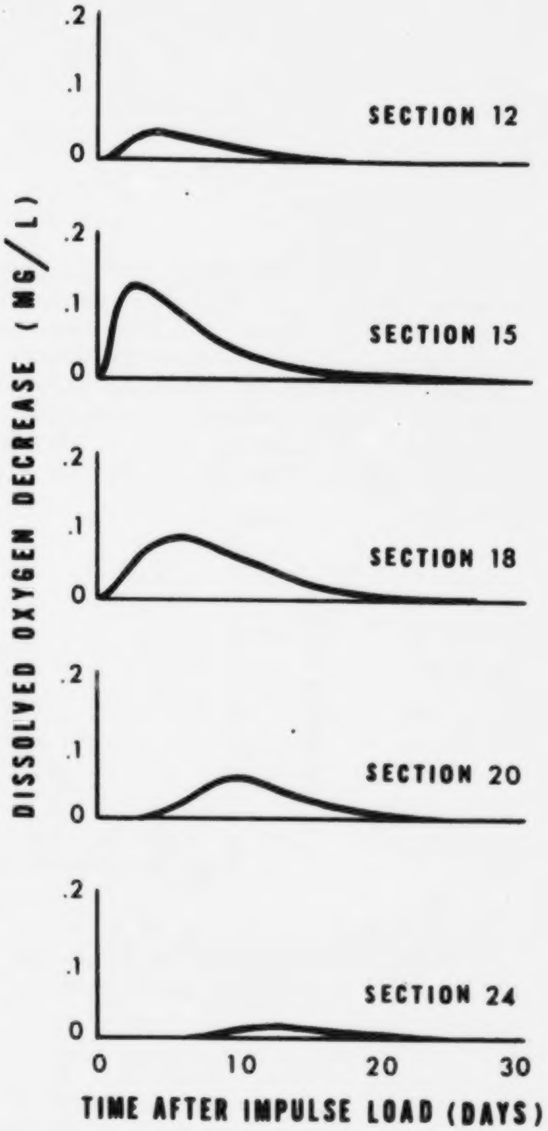

FIGURE 29. - Effect on DO of 200,000# of oxygen demand discharged at one time into section 15.

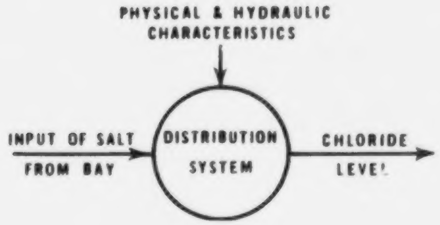

FIGURE 30. - System for chlorides.

The first practical use of the model took place during the summer drought of 1965 when many simulations were used to forecast both the short-term and long-term effects of various flows on salinity intrusion. These forecasts proved to be of significant value in the decision making process relating to control of releases from upstream reservoirs. Figure 31 shows the effect on chlorides in Section 18 of a hypothetical upstream release of 15,000 cfs at Trenton, N. J. for a period of 8 days.

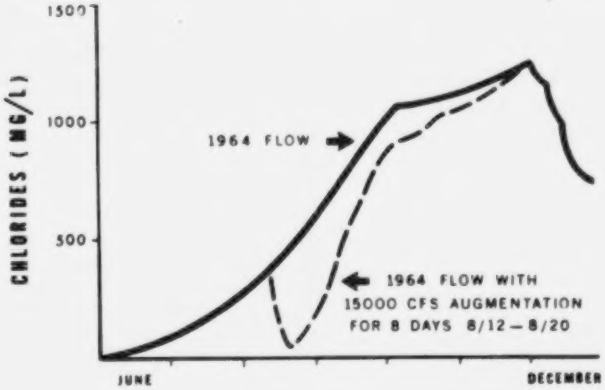

FIGURE 31. - Effect on chlorides in section 18 of simulated input of 15,000 cfs at Trenton, N.J. for 8 days.

Many simulations were made on the effect of both steady state and transient fresh water inflow control schemes on dissolved oxygen. The steady state control schemes showed no definitive improvement with increased flow; the DO profile was displaced slightly downstream. Therefore, the DO was increased in the upper reaches of the estuary but decreased in the lower reaches. However, transient fresh water flow releases of significant magnitude (e.g. 10,000 cfs for 30 days) can be useful in affecting short-term dissolved oxygen improvements.

CHAPTER 5

WATER USES

MUNICIPAL WATER SUPPLY

The combined utilization of surface and ground water by the 35 principal municipal water systems in the study area during 1963 was approximately 550 million gallons daily (MGD). Surface water sources supply about 90% of the total municipal demand. Withdrawals directly from the estuary account for 37% of the total, all of which are utilized by municipalities in Pennsylvania. Ground water accounts for about 60% and 20% of the water used in New Jersey and Delaware respectively, while in Pennsylvania, ground water is the source of less than 2% (see Figure 32). Figure 33 shows the locations of the municipal withdrawal points and the origins of the withdrawals.

There is a significant difference in quality among the available water sources in the area ranging from highly polluted estuarine water to excellent quality ground water. The much higher quality of the latter generally requires less treatment prior to use. However, while ground water is usually more desirable as a municipal water source, sufficient quantity may not be available. Municipalities will then be forced to utilize water and bear the associated higher treatment cost.

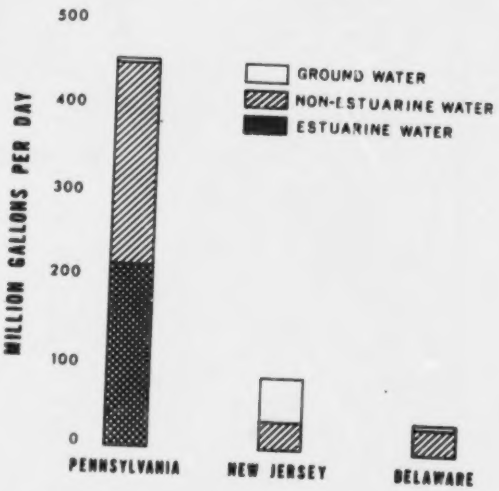

FIGURE 32. - Distribution of municipal water supply by state and source.

Potential users of the estuary have the dual problem of possible contamination from salinity and from municipal and industrial waste. These potential problems are minimal in the uppermost sections of the estuary. Presently three municipal agencies utilize the estuary as a water source; all are in the upper portion of the estuary with the Torresdale facility of the city of Philadelphia being the lowermost user. With a daily withdrawal demand of about 200 million gallons, the Torresdale plant alone accounts for 35% of the total municipal withdrawal in the study area.

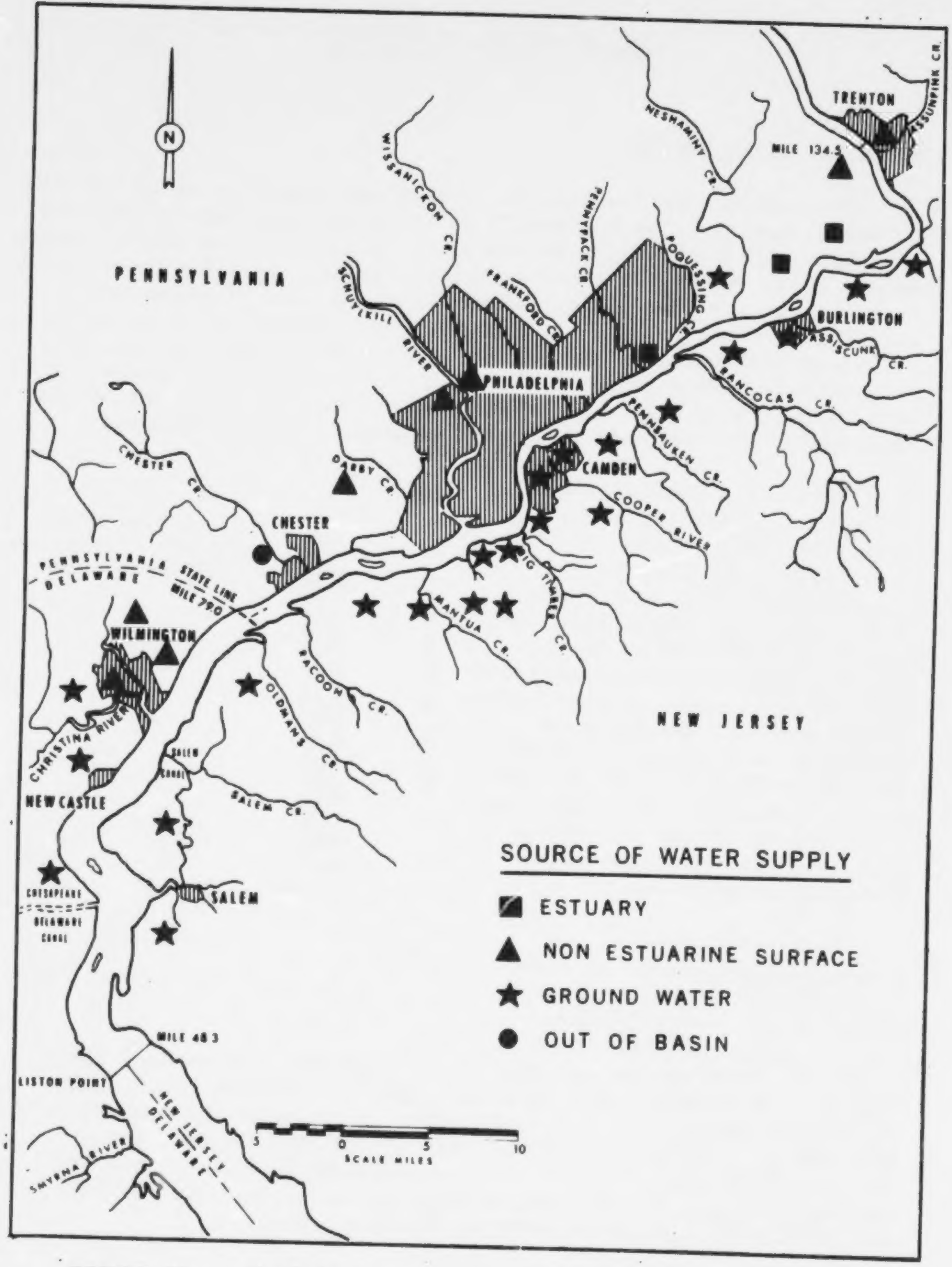
N
PENNSYLVANIA
NEW JERSEY
TRENTON
ASSUNPINK CR.
MILE 134.5
NESHAMINY CR.
WISSAHICKON CR.
PENNYPACK CR.
FRANKFORD CR.
POQUESSING
SCHUYLKILL RIVER
BURLINGTON
ASSISCUNK CR.
RANCOCAS CR.
PHILADELPHIA
PENNSAUKEN CR.
CAMDEN
COOPER RIVER
CHESTER CR.
DARBY CR.
CHESTER
PENNSYLVANIA
DELAWARE
STATE LINE
MILE 79.0
BIG TIMBER CR.
MANTUA CR.
WILMINGTON
RACOON CR.
OLDMANS CR.
CHRISTINA RIVER
SALEM CANAL
SALEM CR.
NEW CASTLE
SALEM
CHESAPEAKE DELAWARE CANAL
MILE 48.3
LISTON POINT
NEW JERSEY
DELAWARE
SMYRNA RIVER
5
0
5
10
SCALE MILES
SOURCE OF WATER SUPPLY
ESTUARY
NON ESTUARINE SURFACE
GROUND WATER
OUT OF BASIN

FIGURE 33. - *Municipal water supply points and origins of withdrawals.*

INDUSTRIAL WATER SUPPLY

The Philadelphia-Camden region is the center of the diverse industrial complex within the study area. Daily industrial water demand is approximately 5 billion gallons of which about 98% is satisfied by surface water sources. The relationship between the volume and geographical location of the industrial water demand along the estuary is presented in Figure 34. Nearly 95% of the industrial demand is used for cooling with the remainder being utilized in processing or for sanitary purposes.

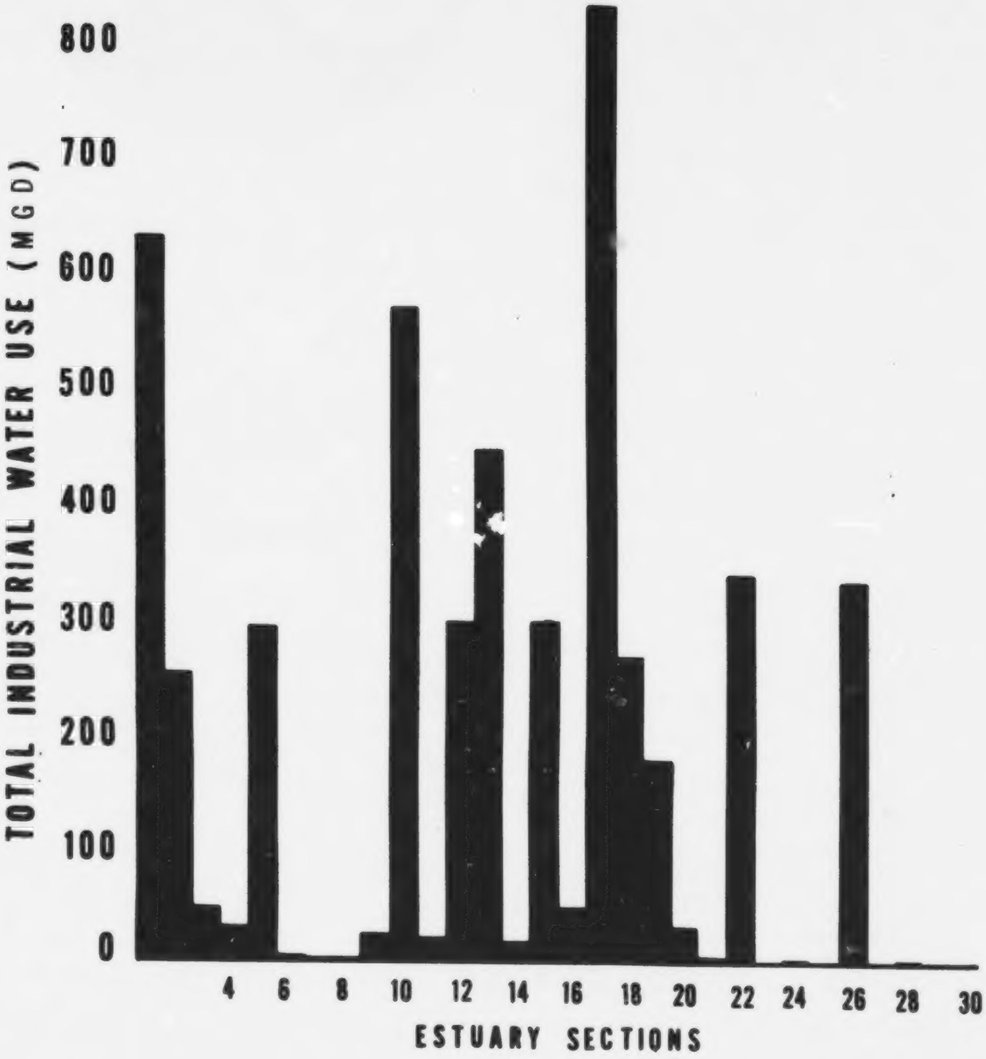

FIGURE 34. - Distribution of industrial water demand along the Delaware Estuary.

Among the several water quality characteristics that affect industrial water use, dissolved oxygen and salinity are of major importance, although other characteristics may be important in specific processes. The quality requirements for cooling water are considerably less stringent than those for municipal supply. Even though some treatment is usually required for cooling water, when using a large volume it becomes more economical to develop a private supply than to purchase municipal water. As a general practice, industry on the estuary has elected private water supply development.

Among the types of industries located on the estuary the electric power generating plants use the greatest volume of water, about 3 billion gallons per day. This volume represents about 66% of the total industrial demand (see Figure 35) although only 9% of the industries are electric utilities. The remaining 34% of the total water use is divided as illustrated in Figure 36.

Table 6 shows a comparison of water use by the various industrial types as defined by the Standard Industrial Classification. Comparisons are given separately for cooling and process water as well as for total volume used.

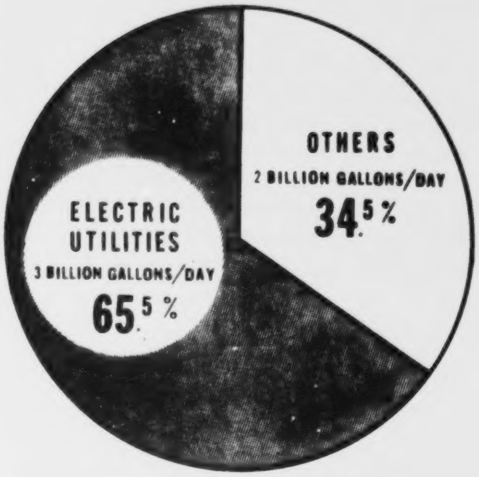

FIGURE 35. - Total industrial water use in study area.

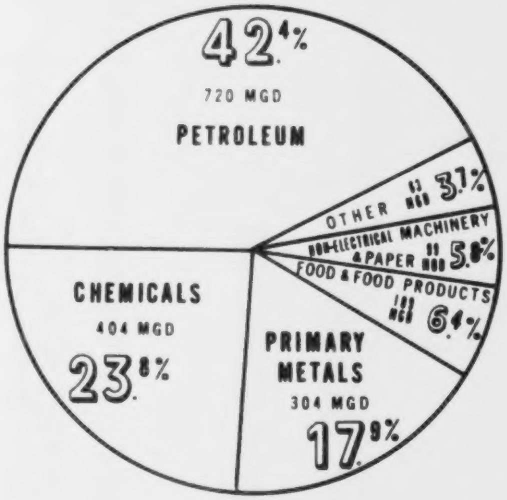

FIGURE 36. - Industrial water use in study area excluding electrical utilities.

TABLE 6

INDUSTRIAL WATER USE COMPARISON IN STUDY AREA

1963

SIC Code	Industrial Type	Process Water (1000 GPD) per Employee	Cooling Water (1000 GPD) per Employee	Total Volume (MGD)
14	Mining and Quarrying of Non-Metals	98.0	-	16.8
20	Food & Kindred Products	6.1	10.3	102.1
22	Textile Mill Products	2.9	-	.9
26	Paper Products	8.4	3.5	41.4
28	Chemical Products	2.4	14.7	398.2
29	Petroleum Products	5.3	50.6	717.0
30	Rubber & Plastics	0.9	.7	2.2
32	Stone, Clay, Glass	1.6	0.5	3.6
33	Primary Metals Industries	3.8	18.0	301.1
34	Fabricated Metal Products	0.1	0.1	3.0
35	Non Electrical Machinery	-	7.0	50.8
36	Electrical Machinery	0.2	1.3	21.7
37	Transportation Equipment	0.2	0.2	1.0
49	Utility Companies	12.1	2282.3	3230.9
				4890.7

RECREATION

Historically, recreation in and along the Delaware Estuary has received a relatively low priority compared to the many possible uses which the estuary can serve. Industrial and urban development along many miles of estuary have eliminated the possibility of developing many types of recreational facilities in certain parts of the estuary.

Present recreational uses of the estuary for swimming, water skiing, pleasure boating, sport fishing and crabbing is but a small fraction of its potential. The present use of the estuary for most of the foregoing activities is severely limited by both poor water quality and limited access.

Boating and fishing are the major non water contact recreational activities in the estuary. The more than 80 marinas and yacht clubs which are located along the estuary berth approximately 10,000 boats. An additional 3,000 individual boats presently (1965) utilize the Delaware Estuary.

The bacterial concentration in the estuary prohibits officially sanctioned use of estuarine water for water contact recreation in many locations. However, many persons disregard this lack of official sanction and some swimming and water skiing occurs throughout the entire length of the estuary.

Table 7 compares the present capacity of the estuary for the listed activities with the present usage. The present capacity of an area results from a calculation of how much officially sanctioned recreational activity can be accommodated in certain locations with the existing facilities. Factors which enter the calculations are, physical size of the area, existing water quality, space required per person for the type of recreation in question, and the length of the recreation season. Recreational capacity and usage are commonly expressed in the units of "activity days", which is defined as a visit by one individual to a recreation area during any reasonable portion of a 24 hour period.

TABLE 7

COMPARISON OF PRESENT CAPACITY AND USE - 1964-65

	Capacity Activity Day/Yr.	Usage Activity Day/Yr.	% Utilization
Boating	8,120,000	1,800,000	23
Fishing	1,620,000	130,000	8
Swimming	0	0	0

A number of factors combine to affect the full utilization of the river, some are general, some are specific to the type of recreational activity. Some general usage factors are the portion of population that is interested in participation in these specific recreational activities, the portion of the population who would rather participate in areas other than the estuary (e.g. the New Jersey Coast, or the Poconos), and the distance people are willing to travel to recreate in the estuary. Other factors affect specific activities. Boating is restricted by the lack of access ramps and the presence of floating debris. Fishing utilization is depressed because the only locations where there is any promise of reasonable sport fishing success are at the extreme ends of the study area. Thus, the satisfactory fishing is a considerable distance from the large centers of population. Swimming is restricted by the presence of municipal waste causing the water in most of the study area to be considered a health hazard from the standpoint of water contact recreation. It is estimated that during 1964-65, there were about 50,000 activity days of unsanctioned swimming. Although available data indicate that the waters of Section #30 may be suitable for water contact recreation, state water pollution control officials have restricted use in that area due to apparently local sanitary conditions.

The unavailability of the estuary for water contact recreation has had several results:

1. Existing investment in public beaches cannot be utilized, e.g. Augustine Beach, Delaware, and Fort Mott State Park, New Jersey, are closed and remain inactive.

2. Revenues resulting from recreational use of the estuary by the general public who would utilize such sites for water contact recreation are lost to the area.

3. Diversified recreation sites that could be utilized for non-water contact recreation (i.e. by individuals who would simply boat or fish) are lost to the general public. Their development is not justified because families cannot also enjoy beaches and swimming.

4. Area parks and recreational facilities are planned without water oriented recreation as a possible use.

Development of park lands along the estuary has been severely restricted. At present there are about 400 acres of park land including historical sites that border the Delaware supporting almost 100,000 activity days/year. Land is available for future development and local and state agencies have prepared several future plans. However, the multi-use character of these proposed parks would be restricted by present water quality.

FISH AND WILDLIFE

From pre-colonial times until the beginning of the twentieth century, the Delaware Estuary fisheries were of great importance to the inhabitants of the region. Indians made substantial use of the piscine abundance prior to the colonists' arrival. The first colonists copied the indian fishing techniques to harvest fish, utilizing the catch locally. By the mid 1820's fish from the Delaware Basin were being exported by wagon and boat not only to places like New York and Baltimore but also to international markets as distant as China.

Records of fish catches prior to 1860 are sparce. Available evidence indicates that good harvests were made in the early 1800's. The peak period for the Delaware Estuary fisheries was between 1885 and 1900 during which time the annual catch by 4,000 fishermen was in the order of 25 million pounds valued at about $4,500,000 at today's prices. Shortly after the turn of the century the annual harvest plummeted, reaching about 1.5 million pounds by 1920. The decline continued to the present annual harvest of approximately 80,000 pounds worth about $14,000. (See Figure 37).

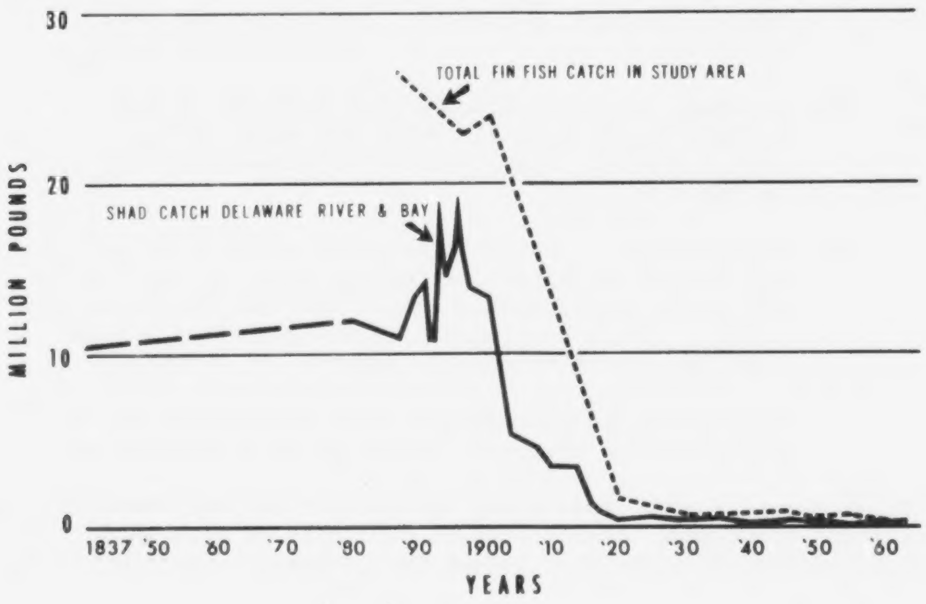

FIGURE 37. - *Historical variation in finfish and shad harvests.*

Shad, sturgeon, striped bass, weakfish, and white perch are examples of the fish which were formerly very important commercially. Of these, the Delaware River sturgeon, reported to have once supplied much of the world's caviar market, is virtually non-existent in the Delaware Basin.

Specific reasons for this sharp decline in the estuarine fisheries are unknown. Promulgated as sharing responsibility for the decrease are such factors as: (1) industrial and municipal waste discharge into the estuary resulting in poor water quality; (2) improper fisheries management allowing overfishing which in turn lowered the existing populations below effective breeding levels; (3) introduction of predaceous fish species into the upper river, thus affecting shad production, an important part of the regional fishery; (4) siltation from farmland, suburban development, and river dredging operations covering spawning areas and reducing the natural production of the aquatic organisms upon which fish feed. Parts of the estuary possess water quality inimical to fish survival, and are therefore quite beyond any consideration being suitable for successful completion of the entire life cycle.

Because of recent changes in technology and processing methods, the Atlantic Menhaden fishery has become extremely important as a source of oil, domestic animal feed supplements, and fertilizer. The value attributable to the menhaden from the estuary is estimated at $1,400,000 annually under present conditions.

There are two areas in the estuary where reasonable good sport fishing is now available; neither area is heavily utilized. The upper estuarine area is between Trenton and Florence, N. J., a distance of eight miles. Presently, sport fishing in this upper area is estimated at approximately 60,000 activity days annually valued at $40,000.

The lower sports fishing area is from Delaware City, Delaware, to Liston Point, Delaware, a distance of about 7 miles. Presently sports fishing in this lower area is estimated at 70,000 activity days valued at $160,000 annually.

The wildlife associated with the estuary are those types which utilize the tidal marshes bordering the river. Virtually all areas where waterfowl could get adequate cover and food have been eliminated between Trenton, N. J., and the Pennsylvania-Delaware state line. In the lower part of the study area, there are approximately 21,000 acres of tidal marsh in New Jersey and 18,000 in Delaware. Waterfowl utilize these areas primarily as resting grounds during the spring and fall migration flights, although limited nesting populations are present. Examples of the birds which frequent these areas are:

black ducks, teal, pintails, canada geese, herons, egrets, rails, and gallinules. While these tidal marsh areas provide very good waterfowl hunting, the maximum commercial use presently is muskrat trapping. The estimated annual return from muskrat pelts is $230,000 which is divided into approximately $130,000 in New Jersey and $100,000 in Delaware.

CHAPTER 6

WATER QUALITY IMPROVEMENT

WATER USE AND WATER QUALITY GOALS

The philosophy in establishing water use and water quality objectives for the estuary was to first investigate all feasible water uses; second, determine water quality criteria to assure these uses; and last, assign water quality goals to the various sections of the estuary according to where the uses were designated. The controlling factor in this procedure is the feasibility of making reaches of the estuary suitable for each of the uses. Literally thousands of combinations of uses versus location could have been investigated for the estuary; but obviously a different approach had to be worked out to limit the number of alternatives.

The method was to elicit a realistic range of water use objectives from the people of the region as represented on the Water Use Advisory Committee. (See Appendix I to this Part). Through this committee, discussions were held concerning possible swimming areas, desirable fishing locations, community desires on withdrawal of water from the estuary, and industrial desires as to water use. The committee was also asked to suggest quality criteria for the various water uses. Based on this work of the WUAC, the alternatives were reduced to five sets of possible water use and associated water quality objectives. Even among these five objectives, different combinations of uses could be devised. It was felt, however, that the five objective sets ranging from maximum feasible enhancement of the river under present technology down to maintenance of present levels of use and quality would provide a sufficient span so that a final set of use/quality objectives could be chosen. It was not necessarily required that the final objective be any one of the individual sets but could be composed of various features from each of the objective sets. For each set, the costs were evaluated and the benefits were described, and where possible, were also quantitatively evaluated. Hence, through a healthy decision making process taking full advantage of all available technical information throughout the discussions, a final set of use/quality objectives could be established. The information flow in this process is depicted in the diagram in Figure 38.

Thus, the water use and water quality goals used in the development of a water pollution control program for the estuary were ascertained through a technical, quasi-political decision making process involving the community of water users and water pollution control administrators in the region.

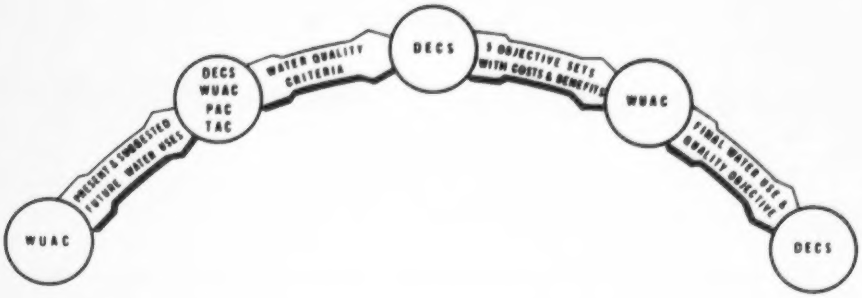
WUAC
PRESENT & SUGGESTED FUTURE WATER USES
DECS
WUAC
PAC
TAC
WATER QUALITY CRITERIA
DECS
5 OBJECTIVE SETS WITH COSTS & BENEFITS
WUAC
FINAL WATER USE & QUALITY OBJECTIVE
DECS

FIGURE 38. - Information flow between DECS and Advisory Committees.

In summary, the five water use/quality objective sets are as follows:

Objective Set I. This set represents the greatest increase in water use and water quality among all of the objective sets. Water contact recreation is indicated in the upper and lower reaches of the estuary. Sport and commercial fishing was set at relatively high levels consistent with the make-up of the region. A minimum daily average DO goal of 6.0 mg/1 is included for anadromous fish passage during the passage periods. Thus anadromous fish passage is included as a definitive part of the water quality management program. Fresh water inflow control will be necessary to repulse high chloride concentrations to Chester, Pa., thereby creating a potential municipal and industrial water supply use.

Objective Set II. The area of water contact recreation is reduced somewhat from that of Objective Set I (OS-I). A reduction in dissolved oxygen (DO) is considered to result in a concomitant reduction in sport and commercial fishing. DO goals for anadromous fish passage remain as in OS-I. Chloride control would be necessary to prevent salt water intrusion above the Schuylkill River.

Objective Set III. This set is similar in all respects to OS-II except for the following three changes. First, the specific DO criteria for anadromous fish passage is not imposed. However, substantial increases in anadromous fish passage will result from the treatment requirements imposed to control DO during the summer assuming that the waste load reductions are carried out during the anadromous fish run periods. Second, a general decrease in the sport and commercial fishing potential is imposed through a lowering of the DO requirements. Third, the quality at points of municipal water supply were reduced.

Objective Set IV. This set represents a slight increase over present levels in water contact recreation and fishing in the lower reaches of the estuary. Generally, quality requirements are increased slightly over 1964 conditions (OS-V) representing a minimally enhanced environment.

Objective Set V. This set represents a maintenance of 1964 conditions, i.e., a prevention of further water quality deterioration.

The water uses protected by each objective set are presented graphically in Figure 39. This chart indicates the sections of the estuary (see Figure 20) for which the various water uses were considered. The associated water quality goals for each objective set have been selected on the basis of the designated uses in each section or group of sections. The most stringent criteria was selected where several uses were designated for the same section.

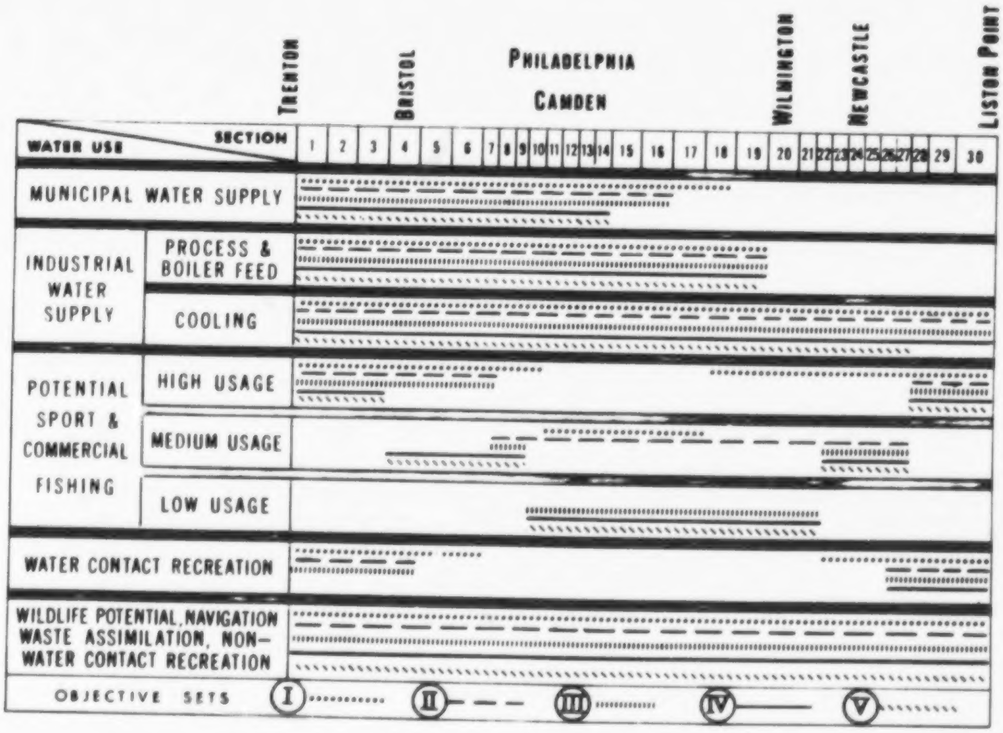

FIGURE 39. - Water uses for Objective Sets I-V.

In all, twelve primary parameters were considered in the development of these objective sets:

1) Dissolved Oxygen (DO) (mg/1)

2) Chlorides (mg/1)

3) Coliform bacteria (No. of organisms/100 ml)

4) Turbidity (Turbidity Units)

5) pH (pH units)

6) Total Alkalinity (mg/1)

7) Phenols (mg/1)

8) Synthetic detergents (mg/1)

9) Total Hardness (mg/1)

10) Temperature (mg/1)

11) Floating Debris, Oils, Grease

12) Toxic Chemicals

The ranges and values of these parameters for each objective set are presented in Tables 8-12.

TABLE 8

WATER QUALITY GOALS FOR OBJECTIVE SET I

	Trenton			Bristol			Torresdale Philadelphia				Camden							Chester		Wilmington				New Castle						Liston Point
Quality[a,b] Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Dissolved Oxygen[c]	6.5					6.5	5.5				4.5						4.5	5.5		5.5	6.5							6.5	7.5	7.5
D.O.[i] 4/1-6/15 & 9/16-12/31	6.5																													6.5
Chlorides[d]																50		250												
Coliforms (#/100 ml.)	5000[e]																	5000[e]	5000[f]											5000[f]
Coliforms 5/30-9/15	4000[e]					4000[e]	5000[e]											5000[e]	5000[f]				4000[e]							4000[g]
Turbidity (Tu)	Natural Levels + 30																													Natural Levels + 30
Turbidity 5/30-9/15	Natural Levels						Natural Levels + 30															Natural Levels + 30	Natural Levels							
pH[g] (pH Units)	6.5-8.5																													6.5-8.5
pH[g] 5/30-9/15	7.0-8.5						6.5-8.5															6.5-8.5	7.0-8.5							
Alkalinity[d]	20-50					20-50	20-120																							20-120
Hardness[h]	95					95	150											150												
Temperature[g] (°F)	Present Levels																													Present Levels
Phenols[h]	.001																	.001	.01											.01
Syndets[h]	.5																	.5	1.0											1.0
Oil & Grease	Negligible																													Negligible
Toxic Substances	Negligible																													Negligible
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

a. mg/l unless specified b. Not less stringent than present levels c. Summer average
d. Maximum 15 day mean e. Maximum Level f. Monthly geometric mean g. Desirable range h. Monthly Mean
i. Average during period stated

TABLE 9

WATER QUALITY GOALS FOR OBJECTIVE SET II

	Trenton			Bristol		Torresdale	Philadelphia					Camden						Chester			Wilmington				New Castle					Liston Point
Quality^{a,b} Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Dissolved Oxygen^{c}	5.5					5.5		4.0											4.0	5.0								5.0	6.5	
D.O.^{i} 4/1-6/15 & 9/16-12/31	6.5																													6.5
Chlorides^{d}														50		250														
Coliforms (#/100 ml.)	5000^{e}					5000^{e}		5000^{f}																						5000^{f}
Coliforms 5/30-9/15	4000^{e}		4000^{e}		5000^{e}			5000^{f}																	5000^{f}				4000^{e}	
Turbidity (Tu)	Natural Levels + 30																													Natural Levels + 30
Turbidity 5/30-9/15	Natural Levels				Natural Levels + 30																					Natural Levels +30			Natural Levels	
pH^{g} (pH Units)	6.5-8.5																													6.5-8.5
pH^{g} 5/30-9/15	7.0-8.5				6.5-8.5																					6.5-8.5			7.0-8.5	
Alkalinity^{g}	20-50					20-50		20-120																						20-120
Hardness^{h}	95					95		150								150														
Temperature^{g} (°F)	Present Levels																													Present Levels
Phenols^{h}	.001					.001		.005								.005	.01													.01
Syndets^{h}	.5					.5		1.0																						1.0
Oil & Grease, Floating Debris	Negligible																													Negligible
Toxic Substances	Negligible																													Negligible
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

a. mg/l unless specified b. Not less stringent than present levels c. Summer average
d. Maximum 15 day mean e. Maximum level f. Monthly geometric mean g. Desirable range h. Monthly mean
i. Average during period stated

TABLE 10

WATER QUALITY GOALS FOR OBJECTIVE SET III

	Trenton			Bristol		Torresdale	Philadelphia					Camden						Chester			Wilmington				New Castle					Liston Point
Quality^{a,b} Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Dissolved Oxygen^{c}	5.5					5.5		3.0												3.0		4.5				4.5		6.5		6.5
Chlorides^{d}														50		250														
Coliforms (#/100 ml.)	5000^{f}																													5000^{f}
Coliforms 5/30-9/15		4000^{e}			5000^{f}																				5000^{f}				4000^{e}	
Turbidity (Tu)	Natural Levels + 30																													Natural Levels + 30
Turbidity 5/30-9/15	Natural Levels				Natural Levels + 30																					Natural Levels + 30			Natural Level	
pH^{g} (pH Units)	6.5-8.5																													6.5-8.5
pH^{g} 5/30-9/15	7.0-8.5				6.5-8.5																					0.5-6.5			7.0-8.5	
Alkalinity^{g}	20-50					20-50		20-120																						20-120
Hardness^{h}	95					95		150							150															
Temperature^{g} (°F)	Present Levels																													Present Levels
Phenols^{h}	.001					.001		.005							.005	.01														.01
Syndets^{h}	1.0																													1.0
Oil & Grease	Negligible																													Negligible
Floating Debris	Negligible																													Negligible
Toxic Substances	Negligible																													Negligible
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

a. mg/l unless specified b. Not less strignent than present levels c. Summer Average
d. Maximum 15 day mean e. Maximum level f. Monthly geometric mean g. Desirable range h. Monthly mean

TABLE 11

WATER QUALITY GOALS FOR OBJECTIVE SET IV

Quality^{a,b} Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trenton			Bristol		Torresdale	Philadelphia					Camden						Chester			Wilmington				New Castle					Liston Point
Dissolved Oxygen^{c}	4.0					4.0		2.5													2.5			3.5					5.5	
Chlorides^{d}												50		250																
Coliforms (#/100 ml.)	5000^{f}																													5000^{f}
Coliforms 5/30-9/15	5000^{f}																								5000^{f}				4000^{e}	
Turbidity (Tu)	Natural Levels + 30																													Natural levels + 30
Turbidity 5/30-9/15	Natural Levels + 30																											Natural Levels + 30	Natural Levels	
pH^{g} (pH Units)	6.5-8.5					6.5-8.5		Present Levels													Present Levels		6.5-8.5							6.5-8.5
pH^{g} 5/30-9/15	6.5-8.5					6.5-8.5		Present Levels													Present Levels			6.5-8.5					7.0-8.5	
Alkalinity^{g}	20-50					20-50		Present Levels																						Present Levels
Hardness^{h}	95					95		150						150																
Temperature^{g} (°F)	Present Levels																													Present Levels
Phenols^{h}	.005													.005	.01															.01
Syndets^{h}	1.0																													1.0
Oil & Grease	Negligible																													Negligible
Floating Debris	Negligible																													Negligible
Toxic Substances	Negligible																													Negligible
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

a. mg/l unless specified b. Not less stringent than present levels c. Summer average
d. Maximum 15 day mean e. Maximum level f. Monthly geometric mean g. Desirable range h. Monthly mean

TABLE 12

PRESENT WATER QUALITY -- OBJECTIVE SET V

Quality^{a,b} Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trenton			Bristol		Torresdale	Philadelphia					Camden						Chester		Wilmington				New Castle						Liston Point
Dissolved Oxygen^{c}		7.0		5.1		5.8								1.0					1.0				4.2						7.1	
D.O.^{h} 4/1-6/15		10.0		8.9		8.7								5.8		4.9			4.3				5.3						7.7	
D.O.^{h} 9/16-12/31		9.0		7.6		6.0									0.9				4.5				8.1						9.5	
Chlorides^{d}							50				100		250		400			1340			2400									
Coliforms (1000/100 ml.) Max.		22		16		280		864				490				460		760		150			170				9.6		9.0	
G.M.		2.6		2.7		6.8		25				63				66		51		22			7				1.9		.7	
Coliforms^{e} (1000/100 ml.)		23		25		40		110					380			300		280		73			26				21		8.7	
Turbidity^{e} (Tu)		139		78		110		112					105			83		130		120			83				75		75	
Turbidity^{e} 5/30-9/15		23		28		29		24					22			24		27		27			37				43		43	
pH^{f} (pH Units)		7.0-8.2				6.9-7.6								6.6-7.4					5.5-7.2				5.2-6.6						6.1-7.0	
pH^{f} 5/30-9/15		7.0-8.7				6.9-7.6								6.6-7.3					6.4-7.0				5.6-7.6						6.1-7.8	
Alkalinity^{f}		25-51				33-46								34-50					13-41				4-25						10-49	
Temperature^{f}		35.6-86.0				34.7-86.0								37.4-84.2				34.7-84.2					35.2-83.8							
Phenols^{g}		.01		.02		.03		.04					.03			.05		.05		.06										
Syndets^{g}		.20		.24		.32		.41					.67			.87		.94		.90										
Hardness^{g}		83										122						467												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

a. mg/l unless specified b. 1964 "Present Conditions" c. Summer average d. Maximum 15 day mean
e. Maximum level f. Present range g. Monthly mean h. Average during period stated

One general feature of these goals is that in no case is the objective for a water quality parameter less than present conditions. A noteworthy point is that each objective set specifies the reduction of floating oils, grease, and floating debris and potentially toxic chemicals to negligible levels. Another important feature is that levels of quality parameters specifically designated for seasonal water use activities may also vary with the season. This is the case for parameters associated with water contact recreation and anadromous fish passage.

Thus each objective set consists of a number of water uses designated at various locations in the estuary. Associated with each of these uses is a list of water quality goals which, if achieved, will satisfy the quality needs of the water uses.

After the costs and benefits of the five objective sets were evaluated, the WUAC began the task of deciding on a final recommendation to the DECS. This work required numerous meetings, discussions, and correspondence involving all members of each of the four subcommittees. If a member was not able to attend a subcommittee meeting, he was informed of all decisions and asked to make comments by letter. In the final analysis then, each subcommittee chairman was able to arrive at a consensus which represented the general attitudes and desires of this group. The members of the WUAC then met and arrived at a consensus of OS-III as the committee's final recommendation to the DECS. (See Appendix II for the WUAC final recommendation.)

During the final phases of the decision making process, efforts were made to further clarify the differences between Objective Set II, Objective Set III, and present conditions (OS-V). One major concern of several parties involved with the decision making process was the deletion of anadromous fish passage as a definitive part of the water quality management program in OS-III. Most persons agreed that a substantial increase in anadromous fish passage would result from OS-III with the control of DO during the summer period. However, a more quantitative description of the differences between OS-II and OS-III with respect to anadromous fish passage was desired.

At this point, an intensive investigation of the waste control programs of OS-II and OS-III as related to anadromous fish was carried out. The analyses utilized a time varying computer simulation model of the estuary to forecast the DO profiles and time series under various flow conditions for oxygen demanding loads for OS-II, OS-III, and OS-V. The analyses considered the passage period, the distribution of passage over time, and the estimated survival rates at different DO levels for both male and female fish. The results are shown in Figure 40, and summarized in Table 13.

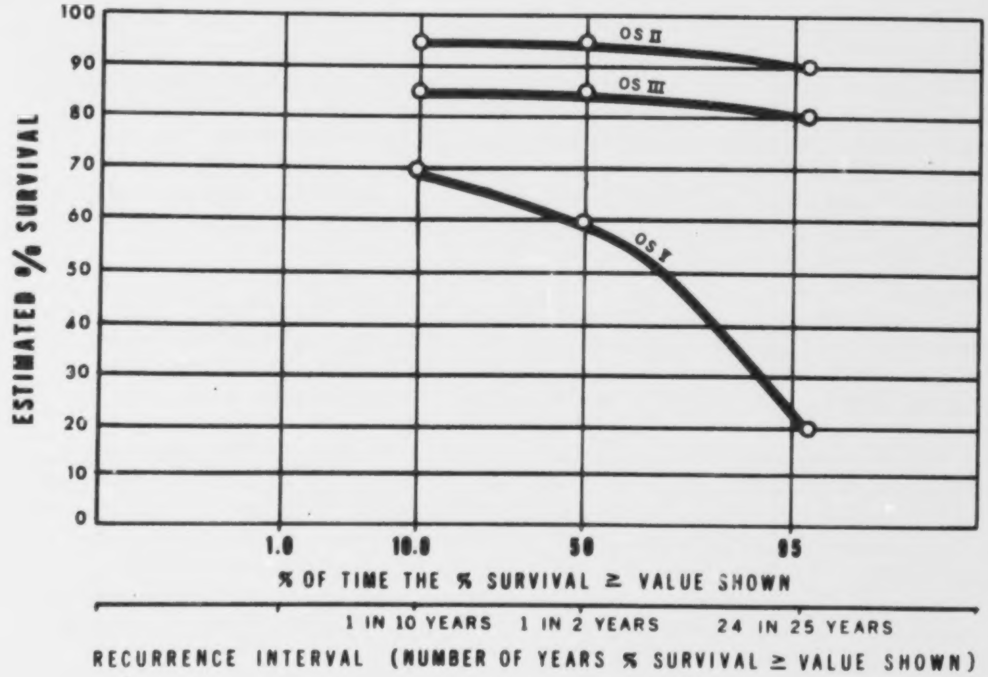

FIGURE 40. - Estimated total (male & female) upstream shad passage for OS-II, III & V (Present conditions).

TABLE 13

ESTIMATED TOTAL (MALE & FEMALE) UPSTREAM SHAD PASSAGE

	Minimum % Survival		
Obj. Set \ Recurrence Interval	1 in 10 Years	1 in 2 Years	24 in 25 Years
OS-II	95	95	90
OS-III	85	85	80
Present - OS-V	65	60	20

Figure 40 shows that under present waste loading conditions (OS-V) the estimated survival 24 out of 25 years is at least 20%; once out of every 2 years, at least 60%; and 1 out of 10 years, at least 65%. Under the waste loading conditions envisioned for OS-III the estimated survival 24 in 25 years would be at least 80%, i.e. once in 25 years the survival would be less than 80%. This reveals that the estimated maximum difference of total shad passage between OS-II and OS-III is about 10% expected survival for both the 24 in 25 years case and in 1 in 10 year flow. A substantial increase in potential shad passage will occur with OS-III over OS-V. This increase in % survival amounts to 60% for 24 out of 25 years.

ALTERNATIVE PROGRAMS TO SECURE DESIRED WATER QUALITY OBJECTIVES

The methods by which water quality may be improved include: 1) limiting effluent discharge to the estuary by requiring reduction of wastes before discharge, 2) piping of the wastes to a place or places where the discharges will have a reduced economic and/or social effect, 3) flow regulation, 4) removal of benthic sludge deposits, 5) in-stream aeration, and 6) control of stormwater discharges. A successful comprehensive program to achieve a particular water use and water quality objective set might incorporate several of these possibilities, but in the final analysis should depend primarily on reduction of waste at the source since this has a higher assurance of successful control. Piping of wastes creates chloride control problems by diverting flow from the estuary and new pollution problems in the discharge area. Maintenance of minimum flows has important chloride control effects but does not significantly alter summer average dissolved oxygen levels. However, transient releases of significant amounts of freshwater inflow can be beneficial in specific instances. Little is known of the practicability of the in-stream aeration of an estuary. The size of the operation may cause difficulties in terms of other uses of the estuary (i.e. navigation, recreation) and in any event would only improve DO without improving other water quality parameters. In-stream aeration can be considered however as a transient supplement to effluent waste removal. Sludge removal and stormwater overflow control also fall into the category of supplemental control measures to be considered in conjunction with effluent control.

There are many ways of controlling the discharge of waste to the estuary to satisfy a specified water quality objective. The problem is to choose a scheme that balances the apparent equity of the solution to the individual waste discharger, the economic cost to the region and the means of administering the water quality management program. Several different categories have been investigated. All relate primarily to the control of waste sources to improve DO. If the control scheme to meet a specific DO objective did not meet all other variables (e.g. bacteria) separate control procedures (e.g. disinfection) were then imposed. The **control programs** investigated are:

1. Uniform treatment - each waste discharger must remove the same percent of the "raw" load (the load before any waste reduction).

2. Zoned-**Uniform** treatment - The estuary is divided into a series of zones and a uniform treatment level (same percentage reduction of the "raw" load) is found for each of the zones that will satisfy the DO goal at least cost to the region.

3. Municipal-Industrial Category - A uniform treatment level is found for all municipalities and another is found for all industries that will satisy the DO objective at least cost to the region.

4. **Cost Minimization** - This program computes the amount of waste to be removed at individual effluent sources so as to secure the DO objective at least cost to the region.

In all of these programs it is assumed that no source will discharge any more waste than is presently being discharged and that all sources which are now below primary treatment (35% removal) will be raised to at least that level.

COSTS OF ALTERNATE PROGRAMS

Forty-four industries and municipalities which comprise approximately 97% of the 1964 carbonaceous oxygen demand waste discharge to the estuary were included in the evaluation of the alternative programs. The underlying systems on which these analyses were based are for steady state flows of 3000 cfs at Trenton. Some additional estimates were made for flows of 4000 and 6000 cfs at Trenton. Best estimates of the decay, reaeration and diffusion rates as well as other physical parameters were supplied by extensive investigation of the physical system. Waste loadings were based on the best estimates available and for the most part were based on actual DECS sampling data. Estimates of costs to reduce waste loadings to the estuary were supplied cooperatively by most of the major dischargers. The dischargers were requested to reflect load increases for about a 10 year period (1975-1980) by estimating the cost of treatment to maintain certain levels of discharge through that time period.

Table 14 shows the estimated costs (construction cost plus the present value of operation and maintenance costs at a 3% discount

TABLE 14

SUMMARY OF TOTAL COSTS OF DISSOLVED OXYGEN OBJECTIVES[1,2]
Flow at Trenton = 3000 cfs

ESTIMATED COSTS IN MILLIONS OF DOLLARS (PRESENT VALUE)

Obj. Set	Uniform Treat.			A-Zoned			B-Zoned			Municipal Industrial Category			Cost Minimization		
	Cap.*	O&M**	Total	Cap.	O&M	Total	Cap.	O&M	Total	Cap.	O&M	Total	Cap.	O&M	Total
I	180	280 (19.0)(3)	460(4)	180	280 (19.0)	460	180	280 (19.0)	460	180	280 (19.0)	460	180	280 (19.0)	460
II	135	180 (12.0)	315(5)	125	150 (10.0)	275	105	145 (10.0)	250	135	180 (12.0)	315	115	100 (7.0)	215
III	75	80 (5.5)	155(5)	55	75 (5.0)	130	50	70 (4.5)	120	75	45 (3.0)	120	50	35 (2.5)	85
IV	55	75 (5.0)	130	40	50 (3.5)	90	40	40 (2.5)	80	50	30 (2.0)	90	40	25 (1.5)	65

NOTES:
1. Costs include cost of maintaining present (1964) conditions.
2. Costs reflect waste load conditions projected to 1975-1980.
3. Annual operation and maintenance costs in millions of dollars/year.
4. HISEC-TER (92-98% removal) for all waste sources for all programs. Includes in-stream aeration cost of $20 million.
5. OS-II & OS-III for all programs include $1-2 million for either sludge removal or aeration to meet goals in Sections #3 and #4.

* Capital Costs
** Operation and Maintenance Costs - Discounted to Present Value at 3% - 20 yr.

rate and a 20 year time horizon) to reach the DO objectives under each of the alternative control programs. Table 15 shows the waste reduction requirements for reaching the DO objectives. The A-zone configuration is exactly the same as the present Delaware River Basin Commission zones in the estuary; Zone A-I extends from Trenton, N. J., to Pennypack Creek, Zone A-II extends from Pennypack Creek to the Pennsylvania-Delaware state line and Zone A-III from the state line to Liston Point, Delaware. The B-Zone configuration divides Zone A-II into two zones: Zone B-I extends from Trenton, N.J., to Pennypack Creek, Zone B-II from Pennypack Creek to the confluence with the Schuylkill River, Zone B-III from the Schuylkill to the Pennsylvania-Delaware state line and Zone B-IV from the state line to Liston Point, Delaware. These zones are shown on the map in Figure 41. Since the waste removal programs were based on DO improvement, the pH and bacterial objectives were not met in all cases. The additional cost of neutralization and chlorination in these cases was also calculated. However, the cost of additional reservoir storage for flow regulation to control chloride levels in the estuary is not included. Table 16 shows the total costs of the alternatives when the costs of chlorination and pH control are added.

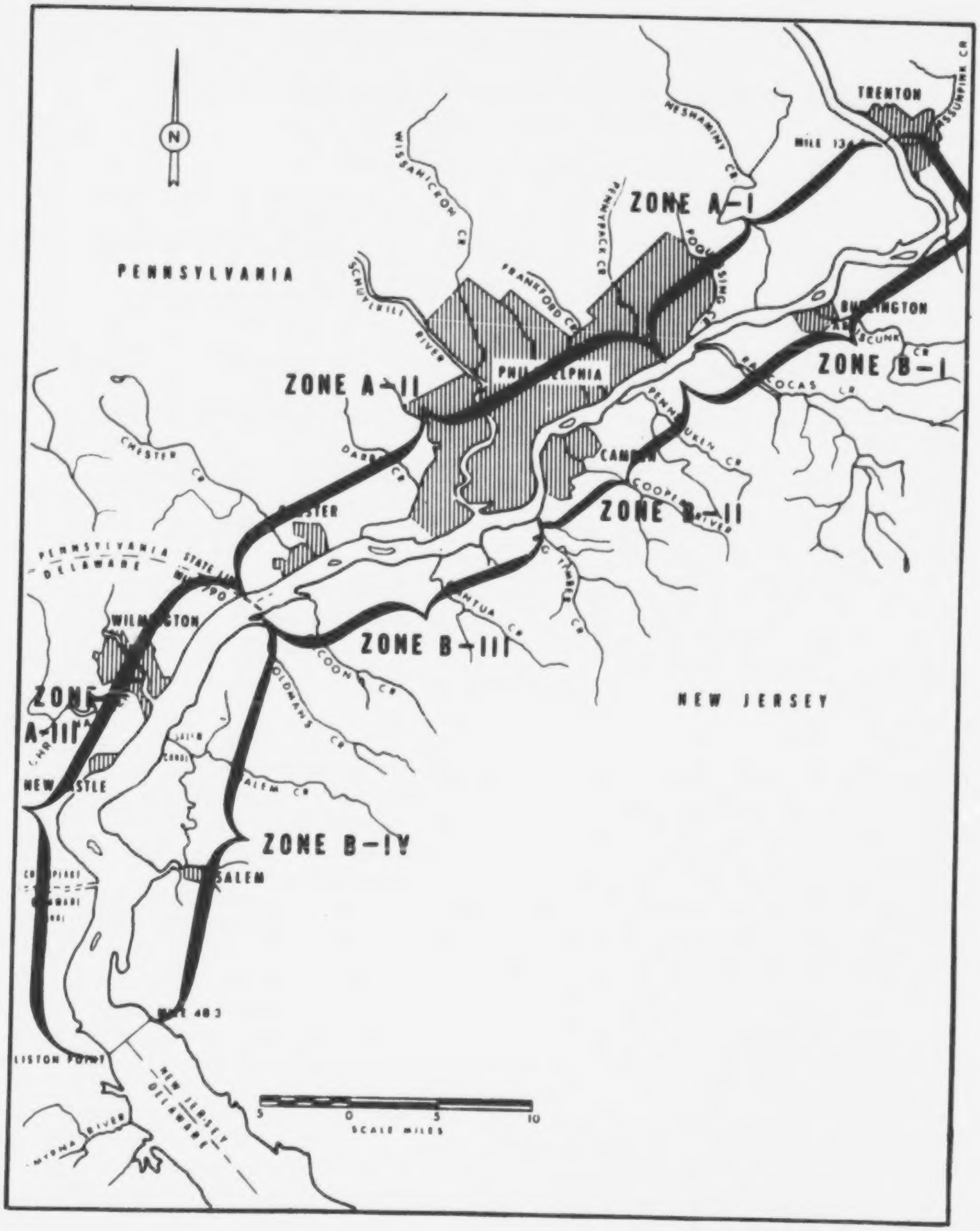
N
PENNSYLVANIA
TRENTON
ASSUNPINK CR
NESHAMINY CR
WISSAHICKON CR
PENNYPACK CR
ZONE A-I
POQUESSING CR
SCHUYLKILL RIVER
FRANKFORD CR
BURLINGTON
RANCOCAS CR
ZONE B-I
PHILADELPHIA
ZONE A-II
CHESTER CR
DARBY CR
CAMDEN
PENNSAUKEN CR
COOPER RIVER
ZONE B-II
CHESTER
PENNSYLVANIA
DELAWARE
STATE LINE
WILMINGTON
MANTUA CR
TIMBER CR
ZONE B-III
RACCOON CR
OLDMANS CR
NEW JERSEY
ZONE A-III
NEW CASTLE
SALEM CR
ZONE B-IV
SALEM
LISTON POINT
NEW JERSEY
DELAWARE
SMYRNA RIVER
5
0
5
10
SCALE MILES

FIGURE 41. - A-Zone and B-Zone configuration used for evaluation of alternative programs.

TABLE 15

SUMMARY OF WASTE REDUCTION REQUIREMENTS TO MEET DISSOLVED OXYGEN OBJECTIVES

Flow at Trenton = 3000 cfs

% REMOVAL BASED ON 1964 WASTE LOADS

Obj. Set	Uniform Treat.		A-Zoned		B-Zoned		Municipal Industrial Category		Cost Minimization	
	No. of Waste Sources Involved	Minimum(1) Treatment (Computed % Removal)	No. of Waste Sources Involved	Minimum(1) Treatment (Computed % Removal)	No. of Waste Sources Involved	Minimum(1) Treatment (Computed % Removal)	No. of Waste Sources Involved	Minimum(1) Treatment (Computed % Removal)	No. of Waste Sources Involved	Treat.(2) Range (Computed % Removal)
I	22M-22I(3)	HISEC-TER (92-98%)(4)	22M-22I	All Zones HISEC-TER (92-98%)(4)	22M-22I	All Zones HISEC-TER (92-98%)(4)	22M-22I	HISEC-TER (92-98%)(4)	22M-22I	HISEC-TER (92-98%)(4)
II	22M-22I	HISEC-TER(5) (90%)	1M-1I 14M-14I 4M-6I	A-I-SEC(5) (85%) A-II-HISEC-TER (90%) A-III-SEC (85%)	1M-1I 5M-4I 9M-10I 4M-6I	B-I-SEC(5) (85%) B-II-SEC (85%) B-III-HISEC-TER (90%) B-IV-SEC (85%)	22M 22I	Municipal HISEC-TER (90%) Industrial HISEC-TER (90%)	15M-16I	PRIM to TER(5) (35-98%)
III	15M-20I	SEC(5) (75%)	1M-1I 11M-14I 4M-4I	A-I-SEC(5) (85%) A-II-SEC (80%) A-III-HI-PRIM-LI (50%)	1M-1I 2M-4I 7M-10I 4M-4I	B-I-SEC(5) (85%) B-II-INT-LS (70%) B-III-SEC (80%) B-IV-HI PRIM-LI (50%)	17M 16I	Municipal SEC (85%) Industrial HIPRIM (45%)	9M-10I	PRIM to SEC(5) (35-85%)
IV	14M-19I	INT-LS (70%)	1M-1I 9M-14I 0M-1I	A-I-SEC (85%) A-II-INT-LS (70%) A-III-PRIM (35%)	1M-1I 5M-4I 7M-7I 0M-1I	B-I-SEC (85%) B-II-SEC (80%) B-III-INT-LS (60%) B-IV-PRIM (35%)	17M 5I	Municipal SEC (80%) Industrial PRIM (35%)	7M-10I	PRIM to SEC (35-85%)

NOTES:
1. Minimum treatment required by solution but not below present treatment level.
2. Treatment range is for all 44 sources. Sources not in solution remain at present level.
3. M=Municipal waste source, I=Industrial waste source (Total # of sources used = 44)
4. Also requires additional control measure such as stream aeration.
5. Requires aeration or sludge removal to meet DO goal in Sects #3&4.

The DO objective for Objective Set I can be reached only by 92-98% removal of all carbonaceous waste sources plus in-stream aeration and dredging of sludge deposits at an estimated cost of 460 million dollars. However, estimating the cost of removals above the 85-90% removal level is difficult since only pilot teritary treatment plant data exist. Thus a program recommending 92-98% removal would require additional work on large scale advanced treatment processes and costs. The cost of attaining the other objective sets differ due to the type of program used. In OS-II and OS-III about 1 to 2 million dollars were necessary for stream aeration in some upper sections to cope with natural undesirable quality conditions. Many sources would have to make

TABLE 16

ESTIMATED TOTAL COSTS OF OBJECTIVE SETS (MILLIONS OF DOLLARS)
Flow = 3000 cfs at Trenton

OS		Uniform	A-Zoned	B-Zoned	Municipal-Industrial	Cost Minimization
I	DO Cost (3)	460	460	460	460	460
	Bact.	30	30	30	30	30
	Total	490	490	490	490	490
II	DO Cost (3)	315	275	250	315	215
	Bact.	20	20	20	20	20
	Total	335	295	275	335	235
III	DO Cost (3)	155	130	120	120	85
	Bact.	20	20	20	20	25(1)
	pH	-	15(2)	15(2)	25(2)	25(2)
	Total	175	165	155	165	135
IV	DO Cost (3)	130	90	80	90	65
	Bact.	15	15	15	15	20(1)
	pH	-	15	15	15	15(2)
	Total	145	120	110	120	100

Notes:
1. To meet bacterial goals, additional chlorine dosages needed by several sources not in DO program.
2. To meet pH goals, pH control needed by several sources not in DO program.
3. Other water use goals (except chlorides) assumed to be met by DO, pH and bacterial control measures. Chloride goal requires fresh water flow regulation. Meeting the phenol goal for OS-I in sections 18-22 may require supplemental phenol control measures. All DO costs include $30 million cost of maintaining OS V.

improvements to keep their present level of discharge as is required for Objective Set V. This cost is approximately 30 million dollars. Five sources must raise their treatment to primary treatment at a total cost of 10 million dollars. These costs of maintaining existing conditions are included in the tables. Studies of these alternatives at different steady fresh water inflows showed changes in costs as the flow increased. Under certain water quality objectives and types of waste reduction program the cost of achieving the DO goal was higher at 6000 cfs than at 3000 cfs. This is basically due to a "shift" in the DO profile requiring certain waste sources to remove additional amounts of waste load at a subsequent additional cost.

If an assured high level (90-95% survival) of anadromous fish passage is desired, while all other water uses are satisfied by OS-III quality goals, DO levels must be raised to OS-II goals approximately 6 months of the year. It is estimated that for fifty percent of the years, this requirement could be met by fresh water inflow controls. At most, the level of this augmentation would be

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about 10,000 cfs for 30 days. The other fifty percent of the years, the DO objectives could be met in either of two ways: 1) in-stream aeration at an estimated total cost (OS-III, B-Zone + assured anadromous fish passage) of 145 million dollars or 2) by requiring waste reduction facilities that are sufficiently flexible to enable operation at OS-II levels during the critical periods and at OS-III levels during the rest of the time at a cost (OS-III, B-Zone + assured anadromous fish passage) of 195 million dollars.

The cost of piping wastes out of the study area was also investigated. Two problems are apparent in the design. The first is that not enough is known of the Delaware Bay environment to assure that the piping of wastes to that area would not create new pollution problems.

Thus more time and money would have to be spent to determine the outfall location. An undesignated area off the coast of New Jersey was therefore used for design purposes. Second, when ocean disposal is considered, a pipeline would divert flow from the estuary which would normally help control chlorides. This would result in an additional cost for chloride control in the form of additional storage in upstream reservoirs. Table 17 presents the capital costs for chloride control as well as for piping of all wastes to the ocean. No estimates have been made of additional costs incurred by the increased pollutional load in the ocean disposal area.

Table 17 indicates that for OS-IV, III and II, waste reduction at the source appears to be less costly on a capital construction basis. For OS-I, the piping alternative becomes more attractive than waste reduction at the source. This is a reflection of the relatively high treatment costs to achieve 92-98% removal of oxygen demand material.

In many regional studies, economies of scale may be obtained by having many small waste dischargers send their wastes to a more efficient regional treatment plant. To a large extent this has already been carried out in the part of the Delaware amenable to consolidation. On the Pennsylvania side, all of the City of Philadelphia, some surrounding municipalities and many industries along the river in the area, comprising 40% of the waste discharges to the the estuary are served by the City of Philadelphia's thre treatment plants. The Wilmington-New Castle County waste treatment plant serves all of the Wilmington metropolitan area and the major portion of New Castle County. The refineries clustered around the Schuylkill and along the Pennsylvania side may, because of the nature of their wastes, find it difficult to discharge to a municipal plant or even to a regional industrial waste treatment unit.The many small communities in the residential complex around Camden, N.J., and in the vicinity of Marcus Hook and Chester, Pa.

would benefit from a regional treatment plant. The industrial waste discharges consist of a relatively few large waste sources at some distance from one another thus precluding a regional industrial treatment plant.

TABLE 17

CAPITAL COSTS FOR ATTAINMENT OF OBJECTIVES (MILLIONS OF DOLLARS)

1) BY PIPING OF WASTES OUT OF THE ESTUARY
2) BY REDUCTION OF WASTES AT THE SOURCE

Obj. Set	Estimated(*) Diverted Flow (cfs)	1) Piping of Wastes Out of the Estuary			2) Waste Removal
		Piping	Chloride Control**	Total	
1	1200	125	40	165	180
2	1150	120	35	155	115
3	300	90	25	115	50
4	650	65	20	85	40

* It is assumed that industrial waste streams will be separated to allow cooling water to return to the stream.

** Estimated Capital Cost of additional storage necessary to counteract effects of diverted flow.

Rough estimates of the total cost (including capital and operation and maintenance) of reaching the various DO objectives by mechanical aeration based on the scale-up of pilot plant data are shown in Table 18.

It should be noted that this meets DO objectives only and additional expense would be necessary to meet other parameter objectives. Since a large scale in-stream aeration such as would be required for the Delaware has never been attempted, considerable study would have to be devoted to the feasibility of the size of the system that is required. It is anticipated that some problems may also develop in interferences with navigation and recreation as well as the creation of nuisance conditions (foaming, etc.)

TABLE 18

ESTIMATED TOTAL COST TO REACH DO OBJECTIVES BY MECHANICAL AERATION

Objective Set	Cost (Millions of Dollars)
I	70
II	40
III	12
IV	10

MAINTENANCE OF OBJECTIVES

If the waste loadings to the stream that are prescribed for each objective set are held constant, that particular objective set will always be maintained. For a particular water quality objective set, the allowable waste discharges vary with the type of a waste reduction program chosen to obtain a solution. Some average estimates, however, can be computed. These are shown in Table 19. Although the total average loads are shown in Table 19, it should be recognized that the geographical distribution of the allowable load is extremely important in achieving the specific objective. Obviously, if the total load were all discharged in one location, an entirely different water quality response would result than if the load were equally distributed along the length of the estuary.

TABLE 19

AVERAGE ALLOWABLE CARBONACEOUS OXYGEN DEMAND

DISCHARGES (#/DAY) FOR OBJECTIVE SETS

Obj. Set V	950,000(1)
" " IV	520,000 - 670,000(2)
" " III	450,000 - 520,000
" " II	150,000 - 220,000
" " I	100,000(3)

(1) This represents estimates of the 1964 carbonaceous oxygen demand discharges to the estuary and differs slightly from estimates of present waste loadings presented in Chapter 3, which represent sampling

data through 1965. The estimates through 1964 were used in the various investigations since the supplied cost estimates were based on these waste loadings.

(2) Different control programs (e.g. uniform treatment, cost minimization) require different amounts of waste removal.

(3) This figure represents the net discharge to the estuary when 92-98% removal of present waste loadings are practical or, in other words, the minimum possible #/day discharge. Additional measures such as in-stream aeration are necessary to raise the DO to meet the OS-I objectives.

The costs shown in Table 14 for achieving the various objectives show estimates of costs of maintaining these discharges for the time period up to 1975-1980. Estimates of future loadings based on economic projections show a substantial increase in waste production in the estuary. To maintain the objective under these increased waste loadings will increase the program cost. To maintain the objectives from 1975 to 1985, it is estimated that the region would have to spend an additional 5.0 to 7.5 million dollars/year.

By 1975, over all treatment levels to maintain OS-IV would approach 80%, for OS-III about 90% and for OS-II, 93% removal of the estimated waste loads will be necessary. By 2010, the estimates of waste loadings before treatment or reduction are so large that 96-99% waste removal will be necessary to maintain the objectives. An estimate of the treatment costs for that time would be misleading for several reasons. First, as waste removal requirements to meet the necessary levels of discharge become more stringent and expensive, other alternatives such as piping of wastes out of the critical areas (see Table 17) water recycling and reuse and in-stream aeration may become more economically feasible alternatives than attempting to achieve higher treatment levels. Second, some industrial waste sources faced with discharge limits might turn to in-plant changes, more efficient process due to advanced technology or perhaps shift production to products which create less waste load in their manufacture. Thus, the means by which the objective selected will be maintained will be largely a function of the future economic alternatives. At the present time the reduction of waste at the sources appears to be the least expensive and most feasible alternative. By 1985-1990 additional treatment to maintain an objective may be more expensive than some other schemes and a new look may be needed at the various alternatives available at that time.

BENEFITS OF INCREASED WATER USE

Intuititively, there are numerous benefits which are derived from water quality enhancement programs. These are realized by a more economic utilization of natural resources, preservation of fish and wildlife, and protection of the region's health and welfare. The value placed upon such general items rests on the judgement of society at large. These intangible items, in essence, provided the impetus for a comprehensive study of the Delaware Estuary. Therefore, one of the basic goals of the DECS has been to better define and quantify the benefits of enhancing water quality in the Delaware Estuary.

Quantification of the benefits is an essential part of any engineering feasibility study. However, in the water pollution control field, the 'state-of-the-art' is new and much methodology is currently being formulated. The DECS did proceed, however, with an analysis of quantifying the benefits for several water uses and for each of the objective sets. It should be noted, however, that from the beginning, it was not expected that all the benefits could be quantified. Certain intangibles will always remain and in those cases value judgments based on the costs of achievement and the qualitative social goals of improvement in quality will have to be made.

For example, in several complex areas, such as water treatment technology, until further basic research is done which correlates the physico-chemical treatment procedures with the quality of the raw water sources, the benefits will remain unquantifiable. The major source of municipal supply that may benefit from improved quality is the Torresdale Water Treatment Plant of Philadelphia. The fact that this plant is able to produce a potable water from an estuarine source of the present quality at a relatively low cost obscures the benefits picture for water supply. It is probable that the net monetary benefits in terms of dollar savings in treatment costs at Philadelphia's Torresdale Plant will be relatively small at the alternative levels of water quality enhancement. What may result, however, after pollution abatement is carried out, will be a reduction in the taste and odor problems and therefore an increase in Philadelphia's ability to produce a more palatable drinking water.

The estimation of industrial water quality benefits is a complex process under the influence of many factors. Among industrial plants, variations in operating policy, type of construction, method of water use, and degree of water treatment must all be considered.

In an attempt to account for these factors, information was obtained from the major water using industries along the estuary.

Data were received on the cost effect of variation of dissolved oxygen and chloride levels in the intake water. These two variables were found to be the most important quality parameters to industrial water users. In most industrial plants, the chain of cause and effect relationships linking river water and monetary savings had not been previously quantified. In spite of the difficulty of such estimates, a number of positive replies were received; many of the non-zero responses were in the petroleum refining, chemical industry, and paper products categories. Other industries such as the electric power utilities indicated no effect for the quality characteristics.

The information supplied by these industries was used to compute statistical estimates of benefits (or costs) for the major water using industries, including those unable to determine their own cost response. For this latter group the annual benefit (dollars per year) was considered to depend on the following variables:

1. Dissolved Oxygen or chloride level, each a function of the Objective Set
2. Location
3. Quantity of estuarine intake water
4. Industrial type
5. Type of use

In terms of location, benefits (or costs) are considered to accrue only in those areas of the estuary exhibiting significant dissolved oxygen increase or chloride depression. These areas are determined primarily by the Objective Sets.

Response-surface analyses were carried out to obtain the statistically best estimate of annual benefit given the input variables for any industry. The total benefit in annual terms is then the sum of individual industry values, where some are based on original interview data and others on the statistical estimates derived from the response surfaces. In all cases the benefits (costs) represent a dollar value which would accrue as a result of steady state (long-term) conditions. The inputs are assumed to be relatively stable at the levels indicated by the Objective Sets over a number of years, with the exception of water use. The latter experiences a secular increase over time projected as shown in Figure 42. The estimated present (1964) value of the benefits (costs) of achieving new dissolved oxygen levels are shown in Figure 43. It will be noted that increased DO results in increased cost (or negative benefits). This is primarily due to increased corrosion rates at the higher oxygen levels.

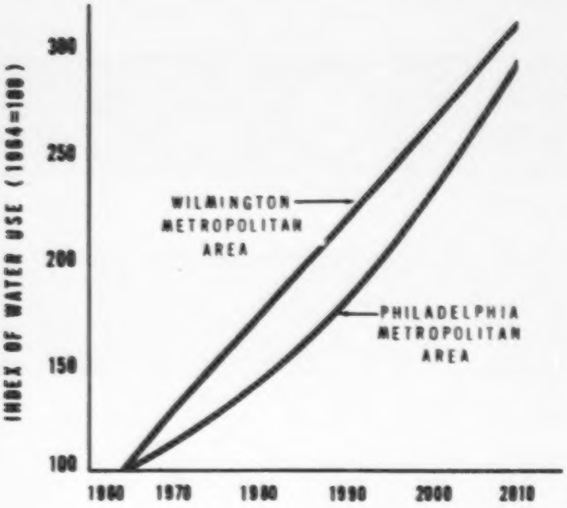

FIGURE 42. - Index of industrial self supplied water use from surface sources.

The benefits derived from chloride control are not related as such to a pollution abatement program. Rather these benefits will result if the required flows are released from proposed Corps of Engineers' reservoirs. Thus chloride costs and benefits can not be compared to other costs and benefits contained in this report. . It is estimated in a report by the Federal Water Pollution Control Administration to the Corps of Engineers entitled, "Water Quality Control Study - Tocks Island Reservoir - Delaware River Basin", June 1966, that a minimum regulated flow of about 4000 cfs at Trenton would meet the chloride goals of Objective Sets II and III. This flow would be achieved under the present up-basin reservoir plan and would result in a benefit to industrial water users of almost $4 million per year. An additional 2200 cfs (to a total minimum regulated flow of 6200 cfs) would be required to meet the chloride goal of OS-I. It is estimated that this would have a direct new quantifiable benefit of $2 million per year over and above the $4 million per year of OS-II and OS-III.

The quantifiable monetary benefits associated with increasing recreational possibilities in the Delaware Estuary have been estimated as part of a cooperative study by the DECS and the Bureau of Outdoor Recreation (BOR) and through a contractual study being carried out by the Institute for Environmental Studies (IES), University of Pennsylvania.

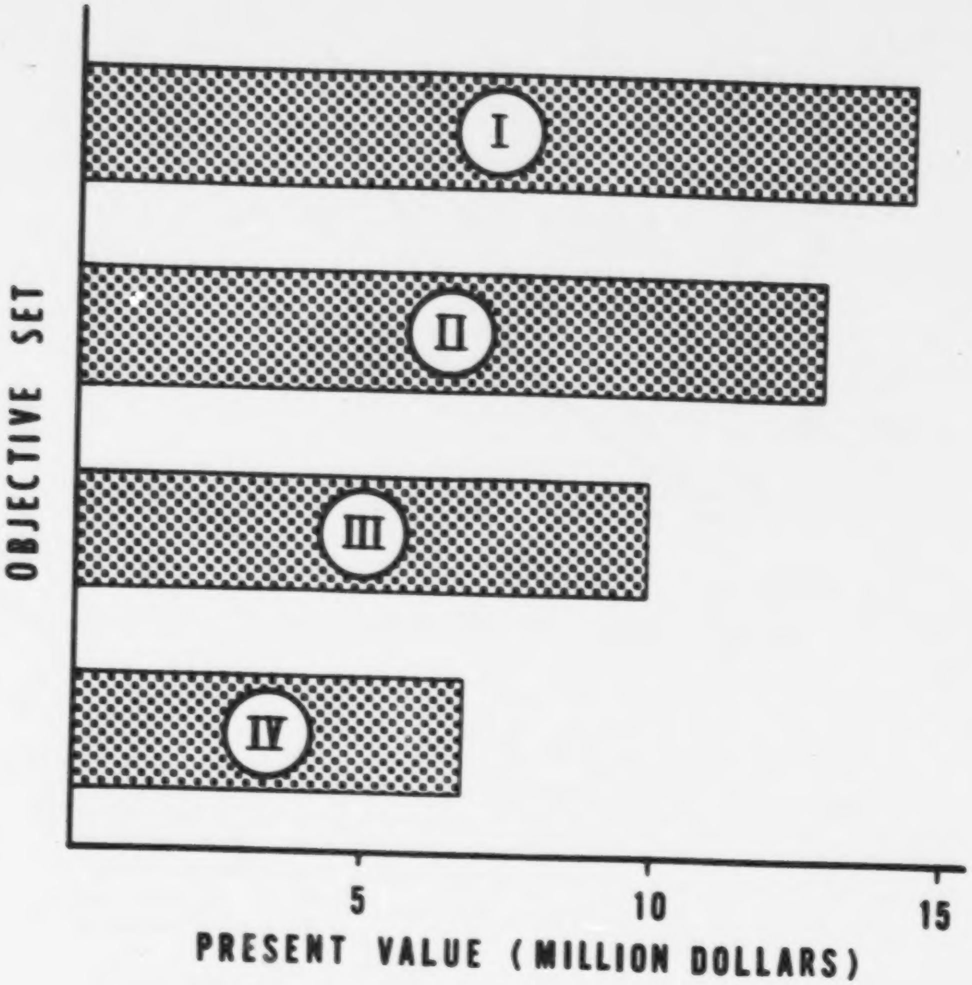

FIGURE 43. - Industrial dissolved oxygen incremental negative benefit (cost) in 1964 dollars.

The general types of recreational activities considered include swimming, boating, and sport fishing. Recreational boating was further broken down into three sub-uses: (a) pleasure boating, (b) pleasure boating associated with fish and (c) pleasure boating associated with fishing and water contact recreation. The benefits due to other activities such as picnicing and sightseeing result from an improved aesthetic surrounding and are non-quantifiable. Sport fishing for shad in the Delaware Basin above Trenton, N. J., was also included since the quality of the estuary directly affects the supply of this activity.

The analyses estimate the net dollar benefits that would accrue in the 1975-20 period from increased recreational possibilities for each of the Objective Sets over present conditions. This was accomplished in general by (1) estimating the total recreation demand in the Delaware Estuary region by applying average national participation rates to the region's present and projected population, (2) estimating the maximum capacity of the estuary under each of the objective sets, (3) estimating the part of the total demand expected to be fulfilled by the estuary, and (4) applying monetary unit values to the estimated total participation demand in the estuary to arrive at total estimated recreation benefits.

Figure 44 presents the estimated present and projected recreational demand in terms of "activity-days" in the Delaware Estuary region. These results show a substantial demand for these types of recreational activities. The analyses have also shown that the estuary has the capacity of a major potential recreation resource and could absorb much of this total demand if water quality conditions are improved and recreational parks, facilities, and access routes constructed.

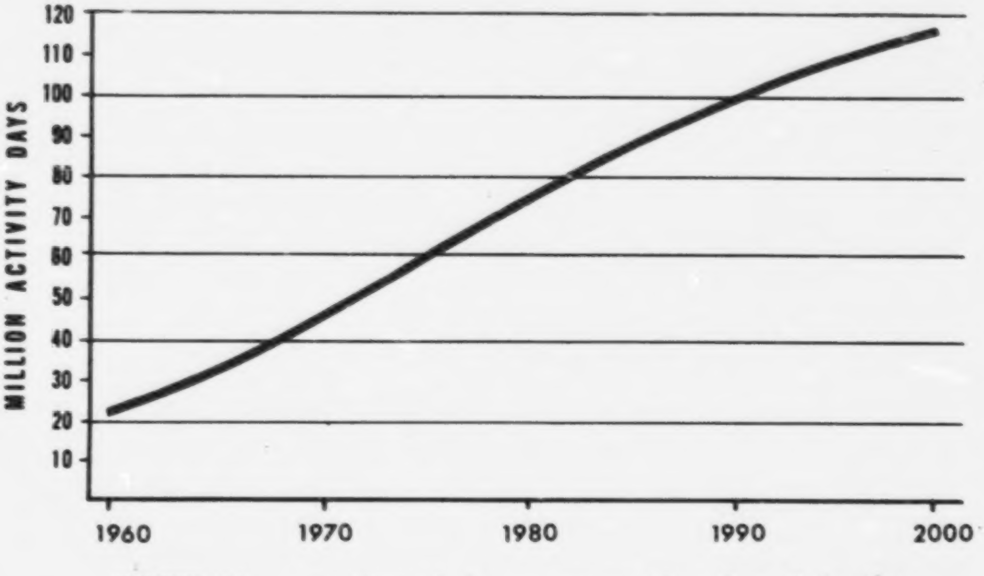

FIGURE 44. - Estimated future recreation demand in the Delaware Estuary region.

The monetary benefits derived from increased recreational usage for each objective set depend on several factors and assumptions. The difficulty in specifying these factors is a result of the present "state-of-the-art" in describing recreational benefits. Thus to avoid specifying one monetary value which may be misleading, a range of values was computed. As additional information is generated

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by the Institute of Environmental Studies, better estimates of the recreational benefits will be available. However, it is expected that any new estimates will remain within the range of benefits reported herein.

The maximum and minimum values of the range of recreational benefits to 1975-80 were computed on the following basis:

1. Water contact recreation benefits

Maximum -- For the maximum net benefit for OS-I thru IV, negligible gross benefits are assumed for OS-V on the basis that no authorized water contact recreation occurs in the estuary. Present quality conditions restrict improvement and construction of recreational facilities and access routes by Federal, state, and local agencies.

Minimum -- Water contact recreation benefits are assumed to accrue under OS-V in an area of marginal water quality in the lower estuary (Section 30).

2. Boating Capacity Estimates

Maximum -- 4 activity days per boat

Minimum - 2.5 activity days per boat

3. Monetary value per activity day based on quidelines presented in the document prepared by the Ad Hoc Water Resources Council, "Evaluation Standards for Primary Outdoor Recreation Benefits".

Maximum -- 25% of usage @ $5.00 per activity day
75% of usage @ $1.25 per activity day

Minimum -- 25% of usage @ $3.00 per activity day
75% of usage @ $0.75 per activity day

In accordance with other economic calculations in this report, the 1975-80 recreation benefits in terms of 1964 dollars are reported as Present Values calculated with an interest rate of 3% and a time horizon of 20 years. The results of the analyses are presented in Table 20 and depicted on Figure 45. Benefits were ascertained by subtracting the value for OS-V from the gross values of the other objective sets. The net marginal benefits are of special importance since they show the change in benefits between objective sets.

TABLE 20

ESTIMATED RECREATIONAL BENEFITS (1975-1980)
MILLIONS OF DOLLARS (PRESENT VALUE)

	Net Benefits/1		Net Marginal Benefits	
OS	Max.	Min.	Max.	Min.
I	355	155	35	20
II	320	135	10	10
III	310	125	30	10
IV	280	115		

/1 Net Benefits above OS-V.

A study was also made to define and quantify the benefits that would accrue to the commercial fishing industry. Although the estuary proper no longer supports a substantial commercial fish harvest, its water quality does influence commercial fish production in adjacent areas.

For shad and other migratory fish, the estuary serves as a passage between their spawning grounds in fresh water and their primary habitate in the sea; it is a place of temporary residence possibly once or twice in a lifetime. For the menhaden the estuary is also a temporary residence; as juveniles, the menhaden move from the ocean into the lower portion of the study area where they grow substantially during their two to three month stay. Finally, the study area is important to the large number of other species which spend most of their lives therein and are considered permanent residents.

When calculating benefits, a given species was considered to be beneficially influenced by improved water quality if it must depend on water within the study area for survival at some period in its life cycle. The commercial fishery attributable to the study area contains three components, the menhaden, the shad, and a composite group of all other commercially harvested species. It is assumed that an increase in the volume of good quality water will support an enlargement of the above fish populations which, in turn, will be reflected in greater commercial fish harvests.

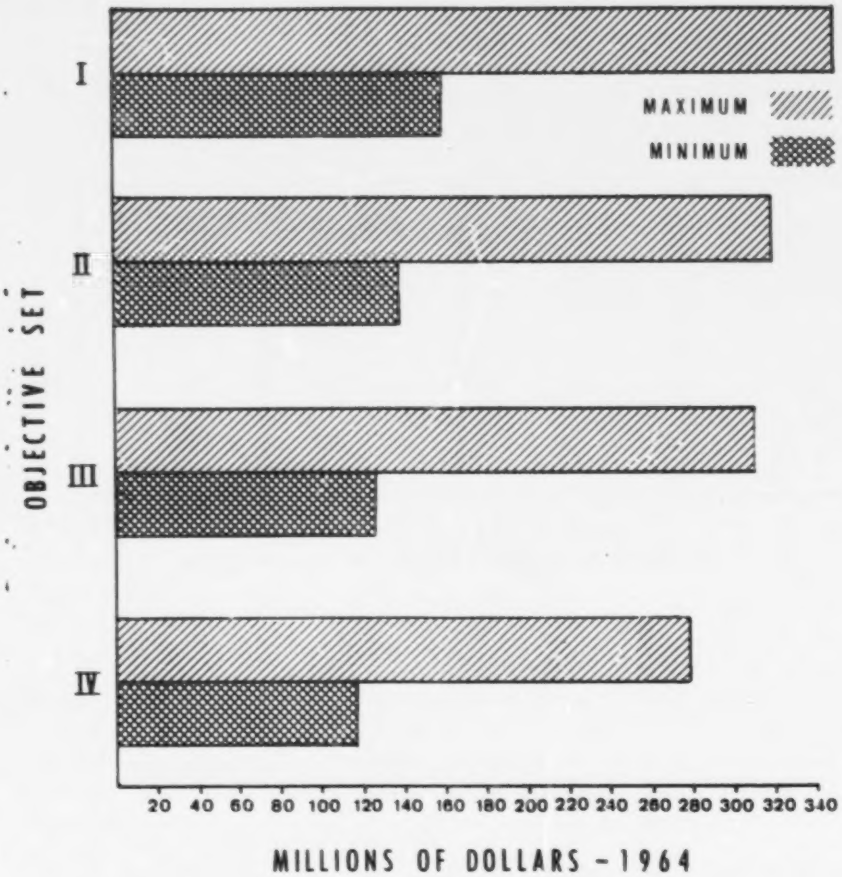

FIGURE 45. - Present value (1964) of recreation benefits from demand satisfied by the Delaware Estuary.

Menhaden are the basis of the largest commercial fishery in the United States. The Delaware and southern New Jersey fishing industry averages about $4,000,000 annually of which approximately $1,400,000 is attributable to fish from the Delaware. Virtually all menhaden caught are reduced to fish meal, condensed solubles, or oil. Most of the meal and condensed solubles are added to swine or poultry feed where they supply vitamins, minerals, and growth factors. Menhaden oil is used in paints, varnishes, and soaps and is also shipped to Europe where it is used in manufacturing margarine.

As the water quality improves with each Objective Set, the volume of water inhabitable by menhaden will also increase. For this estimate, it was assumed that the dollar value of the catch attributable to the Delaware River would increase in proportion to the volumetric increase in inhabitable water. The results are presented in Table 21.

Shad fishery benefits were calculated under two primary considerations, (1) the suggested fishway at the propoosed Tocks Island Dam will not be successful, (2) the fishway will be successful or alternative spawning grounds will evolve. The proposed Tocks Island Dam will probably be a hindrance to the normal migration of shad to and from the principal spawning areas above the dam site. Because of this obstacle, it is the general opinion of biologists that shad spawning success will be considerably reduced in the Delaware River. When developing estimates of the shad fishery under the water quality conditions represented by the different objective sets, the following items were considered: probable size of the attainable harvest, the effect of good fishery management, research into anticipated markets, opportunity to develop new markets, water quality under various flow and waste load combinations, time of year and duration of the annual shad migration, and the dissolved oxygen tolerance of shad. The estimated value of the annual commercial shad harvest is given in Table 21.

In the final category of commercial fisheries are all the remaining species that are harvested on a commercial basis, e.g., croaker, striped bass, weakfish, blue fish, and white perch. The value of these fish caught within the study is quite small, being in the order of $12,000 annually. With pollution abatement programs, new areas of good quality water will be available and in turn should produce more fish. The increased volume of good quality water under various objective sets is reflected in the anticipated harvests for "other finish" as given in Table 21.

It is anticipated that commercial fishing within the study area will be quite limited primarily because of competing uses such as recreational boating, sport fishing, commercial shipping, and waste disposal. However, with improved water quality conditions the lower portion of the study area will increase in value for its two most important functions (1) a nursery area for juvenile fish and (2) an area with a very high production of aquatic organisms which serve directly and indirectly as food for fish which are harvested in abundance elsewhere.

TABLE 21

ESTIMATED NET COMMERCIAL FISHING BENEFITS

PRESENT VALUE

MILLIONS OF DOLLARS

	Menhaden	Shad		Other Finfish	TOTAL	
		Unsuccesful Fishway	Successful Fishway		Minimum	Maximum
OS-1	7.4	1.3	4.0	.3	9	12
OS-2	7.4	1.3	4.0	.2	9	12
OS-3	3.7	1.1	3.3	.2	5	7
OS-4	1.9	.9	2.5	.1	3	5

Another type of benefit results from the effect of the preceding quantifiable direct benefits on the regional economy. These benefits including (1) "induced" benefits that are realized by new or expanded activities in the region and, (2) secondary benefits that are realized by a large number of trade and service industries. These extra benefits are estimated to be in the range of at least 15% of the direct quantifiable benefits.

In addition to the measurable benefits there are numerous other uses that will be improved as a result of increased water quality. The water quality levels presented in the four objective sets would reduce the rate of delignification, corrosion, and cavitation of piers, wharfs, buoys, bridge abutments, and boat engines and hulls. Debris, silt, oils and grease that settle and block channels and intake devices and clog cooling systems in boat engines would be reduced substantially. The dollar benefits attributable to these effects, however, remain undefined.

Another important benefit of increased water quality is the improved aesthetic value of the river. Part of these benefits are reflected in the estimates of increased recreational value. However, these estimates do not include the increase in value of property adjacent to the estuary that will occur by providing a watercourse that is more aesthetically pleasing; nor do the quantifiable benefits include the enhancement of parks and picnic areas adjacent to this watercourse.

The above benefit analyses can be summarized as follows:

For Objective Set IV, which represents a relatively slight increase in water quality, the range of estimated increase in quantifiable benefits is 120 to 280 million dollars. As the objective is raised to Set III, the estimated range in benefits is 130 to 310 million dollars. A further increase in water quality to Objective Set II results in a relatively small increase in benefits -- 140 to 320 million dollars. Finally, the water uses that are associated with Objective Set I are estimated to have a range of quantifiable benefits of 160 to 350 million dollars. Further insight is gained from these figures when the marginal benefits of achieving one objective set over another are compared to the marginal costs.

To go from OS-IV to OS-III would result in 10 to 30 million dollars in additional benefits; whereas, the additional costs as reported in Table 16 of achieving OS-III over OS-IV is about 35 million dollars (assuming a cost minimization management procedure). An additional 10 million dollars in benefits would accrue if OS-II is achieved over OS-III; whereas 100 million dollars in additional expenditures would have to be made. To obtain OS-I over OS-II 255 million dollars more would have to be spent to obtain a 20 to 30 million dollar increase in benefits.

What is apparent from the analyses is that once the water quality reaches a threshold level at which several important legitimate activities may or are assumed to occur, only a small amount of new benefits will result with any additional increase in water quality. For example, once the bacterial standard for water contact recreation is obtained so that swimming and water skiing will be authorized, no further quantifiable benefits will result if the bacterial levels obtained are less than the standard. The important factor is that beaches and facilities may be improved and constructed and recreational usage will increase. What does result, however, with lower bacterial levels in this case is a safety factor in obtaining and maintaining the goals. This however remains unquantifiable.

Another factor to be recognized is that quantifiable benefits are not only related to water quality (ie., areas that may be used for a particular activity) but also the demand for a particular use. In other words, in certain cases the estuary under the objective sets has much more capacity than demand. It is assumed that for all water uses, no quantifiable benefits will accrue from unused capacity. Thus, there are no sport fishing benefits unless there is a fisherman, no industrial benefits without water being pumped, no swimming benefits without a swimmer, and no boating benefits without a boater.

CHAPTER 7

IMPLEMENTATION

GUIDELINES FOR IMPLEMENTATION

A comprehensive water pollution control program is a first step towards a goal of continual water quality management for the Delaware Estuary. The bourgeoning metropolitan and industrial complex which depends on the Delaware for an array of water uses can only be assured of the continuance of these uses through the careful maintenance and management of these resources. Using a sound comprehensive water pollution control program as a basis, policies may be established which will allow the control of long-term and short-term factors which affect water quality in the region. Water quality management for a system such as the Delaware is represented in Figure 46.

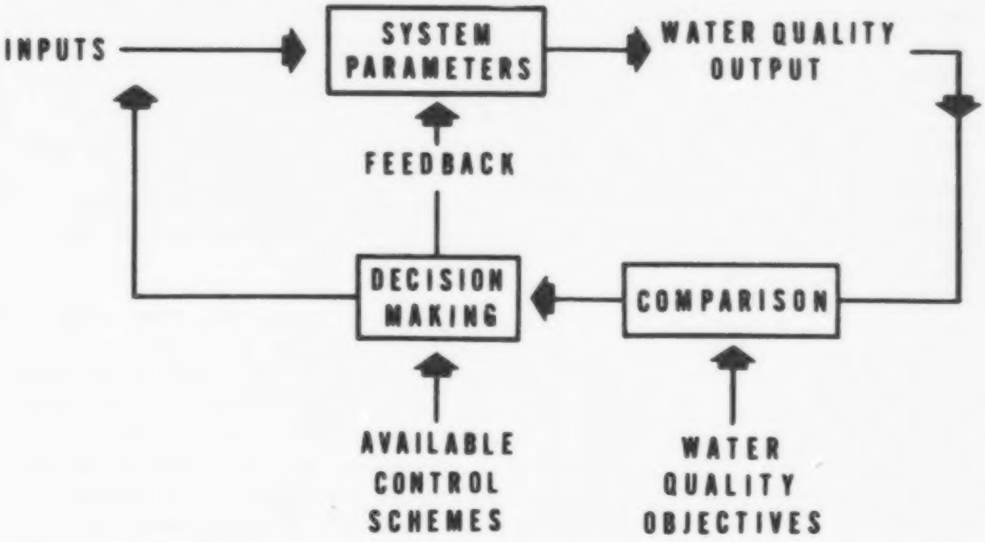
INPUTS
SYSTEM PARAMETERS
WATER QUALITY OUTPUT
FEEDBACK
DECISION MAKING
COMPARISON
AVAILABLE CONTROL SCHEMES
WATER QUALITY OBJECTIVES

FIGURE 46. - Water quality management system.

Successful water quality management will be achieved by the careful updating and refining of the various components of the system and subsequent re-evaluations. The activities that must be performed during implementation to insure the validity of the system are best presented as they affect each system component.

The following are the necessary implementation functions:

a. Evaluation of Inputs - Inventories of the various inputs to the system will have to be carefully updated and sources of wastes monitored as a means of checking compliance with requirements of the program, estimating future trends, and determining the economic effect of the control program. This would include continuation of the sampling of industrial and municipal waste sources, stormwater overflows, tributary loads, and bottom deposits. Special studies of sludge origin and accumulation and of the biology of the estuary would also help pinpoint additional quality depleting materials. Computer analysis of data and rapid addition to a computer aided inventory system such as the Storage and Retrieval (STORET) system of the FWPCA will make the data quickly available.

b. Evaluation of System Parameters - The physical processes that govern the cause and effect relationships between waste inputs and water quality have been characterized by mathematical models. Knowledge of the various physical parameters (e.g. reaeration rates, decay rates) are necessary to construct these models. During implementation it will be necessary to continue investigation of the parameters of the physical system, for instance, new estimates of tidal diffusion and its relationship to flow which can be based on salinity data. Better estimates are needed of flow-runoff relationships. Both analog and digital computers may be used to help in these investigations by aiding in calculations and comparing results with actual conditions for the purpose of verification.

c. Evaluation of Water Quality Output - The knowledge of existing water quality conditions is important as a measure of program success, as a warning of long or short term conditions that might impair existing water uses and thus require control measures, and as a means of verifying and evaluating parameters of the physical system. Continuation and expansion of the existing water quality monitoring system with some means for more rapid availability of data will be carried out. This will be augmented by sampling throughout the estuary. The data obtained will be quickly added to STORET as in the case of input data. Time series analysis of data will give information concerning the timing of control measures for different variables.

d. Evaluation of Water Quality Comparisons and Control Alternatives - Basic policy decisions must be made using the best technical and economic data available as a means of comparison. After a water quality goal is specified, a single program must be chosen from the various control alternatives. This requires a thorough knowledge of the types of control plans available and their costs, investigation into a means of administering the program and allocating the costs and the evaluation of the present and future economic effects such a policy would have on the region. Thus implementation will require continued work on mathematical models used to determine the effects of proposed control programs and the anticipated results of more refined control methods. Since the basis of comparison for these alternatives is economic, it will be necessary to continually update estimates of economic benefits and study the effects of water quality on the economy of the region. The political and administrative arrangements necessary to carry out such a program are manifold. Special emphasis is required on the problems of obtaining cooperation among the various participating agencies and on the dissemination of information to the general public. Careful examination must be given to the potential economic effect of a program because a policy decision could have a profound effect on the future development of the region and on the willingness of water users to go beyond minimum abatement measures. Periodic discussions with water users will provide necessary information concerning the possible need for changing the desired quality goals.

Implementation will best be accomplished through the continued cooperation between the various organizations now concerned with water quality improvement on the Delaware Estuary, the Delaware River Basin Commission, the states of New Jersey, New York, Pennsylvania, and Delaware, and the Federal Water Pollution Control Administration. The primary responsibility for accomplishing the necessary waste reductions would, of course, rest with the states. It is important, however, that there be at least one organization capable of exerting decisive control over the system. In general, the DRBC could perform the main policy functions and have the overall responsibility for the implementation. The FWPCA will continue to provide necessary technical information based on the operation of its mathematical models and other analytical procedures and will make recommendations to the DRBC on technical and policy matters relating to its statutory responsibilities. The states will provide the water quality and waste input data and also make recommendations to the DRBC on similar matters.

A suggested outline for the operational division of the requirements for implementation is as follows:

DELAWARE RIVER BASIN COMMISSION

A. Management and coordination of the Implementation Program

   1. Enlist the cooperation of the states in acquiring data and securing compliance with waste reduction program.

2. Determination and dissemination of decisions and information affecting water quality to water users and the general public.

3. Make requests of the FWPCA concerning the simulations of proposed management programs.

B. Evaluation and determination of desired water quality goals through periodic review by DRBC, water users and the various cooperating agencies.

C. Evaluation of water quality comparisons and control alternatives.

1. Review and evaluate long range control decisions based on technical and policy recommendations of FWPCA and states.

2. Review and evaluate short range control decisions based on technical and policy recommendations of FWPCA and states.

D. Administrative and Fiscal Determinations

1. Investigation and determination of design standards for carrying out program.

2. Development of legal and fiscal means of implementation.

3. Establishment of a timetable for construction and operation so as to accomplish a fully integrated regional plan for water quality management.

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

A. Receive raw data and process for compilation into simple statistical summaries.

B. Put requisite data into the STORET information retrieval system.

C. Updating of previous mathematical model parameter estimations using periodic computer analyses, i.e.

1. Coordination with the U.S.G.S. and/or U.S. Weather Bureau on better description of flow inputs and development of a time varying flow model.

2. Re-estimation of tidal diffusion using observed salinity patterns and development of the relationships between diffusion and flow.

3. A more thorough definition of the reaeration and decay parameters which will require special laboratory studies, field work, and theoretical analyses.

D. Continuation and enlargement of the water quality monitoring system on the estuary. This would include expansion of present facilities to a common parameter system and three or four additional monitoring stations. This would be coordinated with the USGS.

E. Performance of time series analyses to more fully define the time varying characteristics of the various water quality variables.

F. Continual comparison of the forecasts and hindcasts of stream quality with the actual occurrences as more recent data is acquired. Updating computer runs necessary on a 2/month basis.

G. Determination of waste removal performances of all discharges relative to requirements set forth by plans.

H. Computation of optimal short range management programs. This would require estimates of the cost, effectiveness and benefits of transient control devices. Desirable schedule: 0-2/month depending on conditions.

I. Computation of optimal long range management programs. The factors in this case will be new industrial and municipal growth, the cost of new programs, the effect of previous actions, and the benefits to be achieved. Anticipated schedule: 1/year.

J. Modification and expansion of the theoretical basis of the water quality models.

K. Initiation of requests for special studies, e.g.

1. Acquisition of specific biological information.

2. Date acquisition necessary to further refine the system parameters as outlined in Section C above.

3. Investigation of the results to be expected from hypothetical management schemes which may be considered by the DRBC.

L. Investigations concerning the value of particular benefits to the region resulting from real and hypothetical management programs.

M. Specification of laboratory techniques, sampling methods, and reliable standards for the agencies supplying raw data used in the program analyses.

N. Interpretation of results and dissemination to DRBC.

O. Recommendations on technical and policy matters relative to statutory responsibilities for ensuring improvement in water quality.

STATES

A. Assure local compliance with waste reduction requirements of the comprehensive program.

B. Sampling and analysis of the important industrial and municipal waste effluents. This should include (but not be limited to) the following variables: temperature, pH, alkalinity, acidity, conductivity, solids series, nitrate, nitrite, ammonia nitrogen, Kjeldahl nitrogen, BOD, COD, Warburg analyses (with nitrate series), flow. Desirable schedule: 1/month each effluent.

C. Sampling of the estuary which will secure data describing the effect on the estuary of the numerous inputs. Specifically the following variables should be included (others may be added as desired): time, date, water temperature, air temperature, pH, conductivity, alkalinity, acidity, hardness, chloride, phosphate, nitrate, nitrite, ammonia nitrogen, total Kjeldahl nitrogen, BOD, Warburg analyses (not necessarily at every station every week), turbidity, and those biological samples specified in Section G below.

D. Maintenance of the rain gaging network in the city of Philadelphia and possible installation of similar networks in other areas.

E. Continuation of the existing stormwater overflow network in Philadelphia and institution of similar networks where needed (i.e. Camden, Wilmington) until sufficient information is acquired (possibly 3-5 years).

F. Continuation of work on the origin, movement, and importance of bottom deposits. Desirable schedule: 4 runs/year with the expectation that the number will be reduced to 1 or 2 runs/year after three years.

G. Biological sampling involving determination of chlorophyll a concentration, fecal streptococci, fecal coliforms, and total coliform. Desirable schedule: 1/week.

H. Examination of the loadings from the primary tributaries. Desirable schedule: 1/3 weeks.

I. Assistance on special studies, e.g. periodic examinations of benthic and planktonic organisms, fishery population studies.

J. Reporting of all raw data to the Delaware River Basin Commission on a weekly basis.

CHAPTER 8

AREAS OF ADDITIONAL STUDY

The goal of the Delaware Estuary Comprehensive Study was to perform as complete an examination of the complex physical and economic system given specific time and resource allowances. Because of these constraints, some investigations were limited to the specific needs of the study while other investigations were not pursued at all due to a low priority in terms of study needs. The purpose of this chapter is to point out the fields of investigation where additional study will be necessary to effectively describe the system for the implementation of water quality management and to recommend several new areas for study. Many of these requirements have been outlined in Chapter 7 as part of the responsibilities of the implementation program and the reader is directed to that chapter for a discussion of the scope of the program. This chapter amplifies and adds to the functions outlined there.

DELAWARE BAY STUDY

Because of the pressing water quality problems in the estuary, all the resources of the study were expended in characterizing the physical and economic system of the estuarine area. There are many indications, however, that additional effort should now be directed towards a comprehensive study of the bay to insure, for the future, the commercial and recreational uses now enjoyed in the bay. While there does not now appear to be any widespread pollution problems in the bay, this does not mean that present water quality levels will always be maintained. As future needs for waste removal on the estuary increase, more and more pressure will be exerted to divert these pollutional loads to the bay. These loads, combined with future development in the bay area itself, could lead to a curtailment of present water use unless a specific program of preventive pollution control is available. The primary purpose of a bay study, therefore, would be to inventory present water quality and water uses and to develop the necessary technical data and methodology to describe the water quality cause and effect relationships between the estuary and the bay and in the bay itself.

The procedure to be followed in such a study would generally follow that used for the study of the estuary. A complete inventory of existing water uses and waste sources would be necessary. The various physical parameters of the bay environment would be evaluated with additional emphasis on wind conditions and current patterns and on the interaction between the bay and the estuary. Extension of the mathematical models developed for the estuary into a two dimensional system would be required to quantify both the

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steady state and dynamic water quality response to inputs in the bay itself and, also, between the estuary and the bay. Inventories of water uses and economic benefits derived from them as well as other pertinent economic data will aid in the evaluation of comprehensive water quality control plans.

INVESTIGATION OF TREATMENT CONTROL MEASURES

Many water quality problems are of a short term or transient nature and little study has been done on methods to affect short-term quality increases or to protect the water user against the damages caused by temporarily decreased water quality. One of the most pressing problems is increasing DO for short periods in specific areas which would allow fish passage during migratory periods or to counteract other short-term undesirable conditions due to pollutional loads caused by dredging, construction, or treatment plant bypasses. Little research has been done on the feasibility of large scale mechanical aeration. Many questions must be answered, for instance: costs, possible nuisance effects, spacing, oxygen transfer rates, and benefits created.

Other transient situations involve accidental dumps of other wastes such as acids or oils. Investigations would determine the type of control measures different water users could follow (e.g. additional treatment, neutralization, or curtailment of water use). An important part of any transient load control system should be a warning network which alerts water users who must take action.

STORMWATER OVERFLOWS

In the requirements for implementation discussed in Chapter 7, one function was a continuation of the stormwater sampling program. These data should form a basis for the formulation and evaluation of new control methods and for a comparison of control alternatives. It is suggested that the region seriously consider the advantages of a stormwater demonstration project to counteract the undesirable aesthetic effects of combined sewer overflows. Such projects are authorized by Section 6 of the Federal Water Pollution Control Act as amended. These projects may be in the form of a contract or a grant. In a contract, the Federal Government would provide funds to conduct field investigations, experiment with new or improved methods for treating stormwater in combined overflow and to evaluate the application of theoretical concepts related to this problem. A grant would use Federal funds matched by state or local funds in the construction of stormwater treatment facilities.

INVESTIGATIONS OF SECONDARY EFFECTS

In the event that an abatement program is initiated which requires a large amount of secondary treatment, the carbonaceous oxygen demanding load in the river will be drastically reduced and the nitrogenous oxygen demanding material will constitute the main source of oxygen demand. It therefore seems important that an analysis be conducted to determine the effect which nitrogenous loads have on water quality. This would mean the development of a working nitrogen cycle mathematical model with capabilities to compute dissolved oxygen response. This would provide a means of estimating the shift of the location of nutrients such as ammonia and nitrate. To develop this working model it would be necessary to study further the rates of decay associated with the separate phases of nitrification and to develop a computer program to handle the computations involved with a four system model.

COST ALLOCATION

An investigation should be undertaken of the numerous types of effluent charges which may serve as a means of allocating costs, a way of allowing new industrial development, and an economic waste reduction incentive for waste dischargers. Recognizing the controversial nature of the concept of effluent charges, any study should allow for a thorough exposition of all opinions on the subject through cooperative regulatory, municipal, and industrial endeavor.

MANAGEMENT OF THE CONTIGUOUS ENVIRONMENT

The DECS' pollution control program describes the procedures necessary to achieve several different levels of water quality and use. These determinations tacitly assumed that the contiguous environment would be managed so as to take full advantage of the improved water quality. Thus, for example, although bacterial levels may be improved for swimming, suitable peripheral facilities must be provided. Also, while dissolved oxygen levels will be improved to provide water quality for enhanced fisheries, effective fish management must accompany the water quality improvement to guard against overfishing, further needless destruction of spawning areas, and inadequate fish passage through dam and reservoir projects. A need exists, therefore, to investigate the best means of achieving this total management of the water resource associated environment so that the estimated water use benefits of the proposed programs are realized. This will require close coordination, effort, and understanding between many different government agencies and water users.

BENEFITS ANALYSIS

Closely related to the above is the need for an analysis of benefits, especially those benefits derived from recreation. This will entail development of data defining the amount and distribution of expenditures by public for specific recreational activities, the demand for different types of recreation, the factors which determine the capacity of areas for specific recreational activities, and the relationships between ease of access and utilization of recreational activities. This information could be obtained by a systematic counting of recreation area participants supplemented by a public questionnaire.

In order to more reliably estimate the capacity of the estuary to support commercial and sport fisheries, additional information is needed on the location, species, and size of the resident fish population, the potential annual fish harvest, and the important spawning and nursery areas in both the estuary and bay. Most importantly, information is required on the link between water quality, fish populations and catch/unit effort. Market research is necessary to determine trends in the present markets and potential markets for edible and non-edible fish products.

The tidal marshes must be studied in relation to their role in nutrient production, flood control, and the production of microscopic food organisms necessary to the indigenous finfish and shellfish of the upper estuary and bay. Such a study would yield important information that will then be available when considering the utilization of the tidal marshes for industrial expansion, urban development, or sites for dredging spoils.

APPENDIX I

DELAWARE ESTUARY COMPREHENSIVE STUDY

COMMITTEE STRUCTURE

APPENDIX I

D.E.C.S. COMMITTEE STRUCTURE

Direction for the formation of the Delaware Estuary Comprehensive Study's Advisory Committees was derived initially from the Federal Water Pollution Control Act (Public Law 660), Section 3(a):

> "The Secretary shall, after careful investigation in cooperation with other Federal Agencies, with other Federal Agencies, with State water pollution control agencies and interstate agencies, and with municipalities and industries involved, prepare or develop comprehensive programs for eliminating or reducing the pollution of interstate waters..."

Thus, to meet these requirements, of Section 3(a), P.L. 660 as amended, the DECS with assistance of the states and the Delaware River Basin Commission (DRBC), developed a supporting Committee Structure which was designed to meet the requirements of the estuary region.

The following outline presents the Committee Structure which has been in operation for essentially the entire developmental phase of the DECS.

1. Policy Advisory Committee

   Criteria for Membership:

   Agencies with the legal power to abate water pollution and to implement a comprehensive plan.

   Agencies and Members:

   Delaware Water Pollution Commission
   Floyd I. Hudson, M.D., Executive Secretary, State Board of Health
   John Bryson, Director, Water Pollution Control Commission

   New Jersey Health Department
   Alfred H. Fletcher, Director, Division of Environmental Health
   Robert Shaw, Asst. Director, Division of Environmental Health

Pennsylvania Health Department

Karl M. Mason, Director, Bureau of Environmental Health (deceased)

Walter A. Lyon, Director, Division of Sanitary Engineering

Delaware River Basin Commission

James F. Wright, Executive Director

Herbert Howlett, Chief Engineer

Federal Water Pollution Control Administration

Earl J. Anderson, Regional Program Director, Region II (Chairman)

Everett L. MacLeman, Project Director, DECS - 4/66

Edward V. Geismar, Acting Project Director, DECS

2. Technical Advisory Committee

Criteria for Membership:

I Agencies participating in work of study

II Personnel familiar with technical aspects of water quality control

Agencies and Members:

Delaware Water Pollution Commission

N. C. Vasuki, Assistant Engineer

New Jersey Health Department

Harry H. Hughes, Principal Health Engineer

Pennsylvania Health Department

Chris Beechwood, Regional Engineer, Region VII

Kenneth Schoener, Asst. Chief, Stream Quality Section, Delaware River Basin

Delaware River Basin Commission

John Egan, Head, Water Quality Branch

City of Philadelphia

Joseph Radziul, Chief, Research & Development Unit, Water Department

Industry

Lloyd Falk, Waste Consultant, E.I. DuPont de Nemours & Co.

U. S. Fish and Wildlife Service
George Spinner, Supervisor, Bureau of Sport Fisheries and Wildlife

Bureau of Outdoor Recreation
Bruce Stewart, Northeast Regional Office

Federal Water Pollution Control Administration
Robert V. Thomann, Technical Director, DECS (Chairman)

3. Water Use Advisory Committee

Agencies and Members:

Recreation, Conservation, Fish and Wildlife
Edmund H. Harvey, President, Delaware Wildlife Federation

General Public
Frank W. Dressler, Exec. Director, Water Resources Assoc./Delaware River Basin
Paul Felton (Replaced Mr. Dressler in 12/65)

Industry
William B. Halladay, Supervisor-Pollution Control, The Atlantic Refining Co.

Local Governments and Planning Agencies
Carmen F. Guarino, Chief, Sewerage Operations, City of Philadelphia

Federal Water Pollution Control Administration
Everett L. MacLeman, Project Director, DECS (Chairman)
Edward V. Geismar, Project Director, DECS (Chairman) - (Replaced Mr. MacLeman 4/66)

Subcommittee Membership

(1) **Recreation, Conservation, Fish and Wildlife**

A. Shellfish Industry
B. Audubon Society
C. Pennsylvania Pleasure Boat Association
D. Delaware River Yachtsmen League (Corinthian Yacht Club)
E. Pennsylvania Federation of Sportsmen's Clubs
F. New Jersey Federation of Sportsmen's Clubs
G. Delaware Wildlife Federation
H. Izaac Walton League
I. Philadelphia Conservationists

J. Outdoor Writers' Association of America
K. Marine Resources Committee
L. Delmarva Ornithological Society
M. Brandywine Valley Association
N. Wilmington Garden Club
O. Delaware Federation of Garden Clubs
P. Citizen's Committee for Parks

(2) General Public

A. WRA/DRB
B. League of Women Voters
C. Federation of Women's Clubs
D. Delaware Valley Council
E. Joint Council of Pennsylvania Farm Organizations
F. New Jersey Farm Bureau Federation
G. New Jersey Stage Grange
H. American Water Works Association
I. Delaware State Grange
J. Water Pollution Control Federation
K. Delaware River Watersheds Assoc.
L. Pennsylvania State Chamber of Commerce
M. New Jersey State Chamber of Commerce
N. Delaware State Chamber of Commerce
O. Greater Philadelphia Chamber of Commerce
P. Pennsylvania Economy League
Q. Forward Lands, Inc.
R. American Society of Civil Engineers
S. Greater Philadelphia Movement
T. Philadelphia Suburban Research Co.
U. Bucks County Health Department
V. Philadelphia Water Department
W. Neshaminy Watersheds Assoc.
X. Gloucester County Citizen's Assoc.

(3) Industry

A. N. J. Manufacturers' Assoc.
B. Pa. Manufacturers' Assoc.

Petroleum

A. Texaco, Inc.
B. Gulf Oil Corp.
C. The Atlantic Refining Co.
D. Mobil Oil Co.
E. Sinclair Refining Co.
F. Sun Oil Co.
G. Tidewater Oil Co.

Steel

A. U. S. Steel Corp
B. The Colorado Fuel and Iron Corp.
C. H. K. Porter Co., Inc.

Electric Utilities

A. Public Service Electric and Gas Co.
B. Philadelphia Electric Co.
C. Atlantic City Electric Co.
D. Delaware Power & Light Co.

Paper

A. Paterson Parchment Paper Co.
B. Bestwell Gypsum Co.
C. MacAndrews & Forbes Co.
D. Scott Paper Co.

Food

A. Kind & Knox Gelatin Co.
B. National Sugar Refining Co.
C. Campbell Soup Co.
D. National Dairy Co.
E. Pepsi-Cola Co.

Chemical

A. Hercules Powder Co.
B. Cary Chemical Co.
C. Rohm & Haas Co.
D. Allied Chemical Corp.
E. Harshaw Chemical Co.
F. E. I. DuPont de Nemours & Co.
G. Shell Chemical Co.
H. Pa. Industrial Chemical Corp.
I. The Monsanto Co.
J. Atlas Chemical Ind., Inc.
K. N. J. Zinc Co.
L. FMC Corporation

Miscellaneous

A. Eastern Gas & Fuel Assoc.
B. Radio Corp. of America
C. Westinghouse Electric Co.
D. Linde Co.

Miscellaneous (Cont'd)

E. Stokely Van Camp Co.
F. California Packing Co.
G. Ruberoid Co.

Distillers

A. Publicker Industries, Inc.

(4) Local Governments and Planning Agencies

A. City of Burlington
B. City of Bristol
C. City of Camden
D. City of Chester
E. City of Dover
F. City of Philadelphia
G. City of Trenton
H. City of Wilmington
I. Regional Conference of Elected Officials
J. Delaware State Planning Commission
K. Delaware River Port Authority
L. N. J. League of Municipalities
M. N. J. Bureau of State & Regional Planning
N. Penn-Jersey Trans. Study
O. Pa. State Planning Branch
P. Pa. State Assoc. of Boroughs
Q. Pa. League of Cities
R. Pa. State Township Supervisors Assoc.
S. Pa. Municipal Authorities Association
T. Lower Bucks County Municipal Authority

The functions of each Advisory Committee have been as follows:

1. Policy Advisory Committee

   a. Attain consent among states on pollution abatement policy and plans and assure full coordination of effort and understanding.

   b. Coordinate and assist in the inclusion of established water pollution control plans in the overall comprehensive water pollution control plan.

   c. Relate the DECS to possible interim procedures for pollution abatement.

   d. Advise the Federal Water Pollution Control Administration during the developmental phase of the DECS and during future phases.

Members of the Policy Advisory Committee have also been responsible for representing those state and federal agencies with related water resources programs.

2. Technical Advisory Committee

    a. Keep the agencies represented, appraised of the DECS -- in this manner each agency has one person who has had a complete understanding of the technical phases of the DECS.

    b. Assist the FWPCA in planning and coordinating DECS.

    c. Provide technical assistance.

        1. assist in organizing various projects

        2. provide supplemental qualified technical personnel for special phases of the study

        3. review preliminary drafts of reports.

        4. advise the Policy and Water Use Committees on technical matters.

3. The Water Use Advisory Committee

    a. Advise the DECS on the water use and water quality needs and desires of the people in the estuary study area.

    b. Act as a public relations group.

    c. Assist in special non-technical phases of the DECS

The philosophy of organizing advisory committees in the development of comprehensive plans was implied in Section 3(a) P.L. 660 (see above). The Congress realized that the success of any pollution control plan, both in its development and implementation, depends on the cooperation and participation of all government agencies, industry, and civil organizations whose interests would be affected. In view of the complexity of the problem the assistance to be secured through such cooperation and varied participation was immeasurable. The objective, then, of the DECS was to develop a rational pollution control plan, commensurate with needs and economy of the region, according to the abatement procedures either in existence or developed through a cooperative effort. The intention was to reveal through the committees to all representatives the plans and ideas, both technical and administrative, for comment and criticism. A plan developed in this manner would be most easily implemented since those responsible for implementation would have had a share in the development of the plan.

1. Policy Advisory Committee

The Policy Advisory Committee met seventeen times between July 25, 1963, and June 1, 1966. The written minutes of these meetings have been made available to the members of all three advisory committees and other state and federal governmental agencies who have an interest in the work of the study.

The committee has functioned extremely well and has carried out its initial assignments. The success of the committee can be mainly attributed to the energetic participation of the individual members.

One of the important developments evolving from the PAC has been the establishment of direct working relationships among the five primary agencies (State of Delaware, State of New Jersey, Commonwealth of Pennsylvania, Delaware River Basin Commission, and the Federal Water Pollution Control Administration) toward the main objective of pollution control in the Delaware Estuary. Specifically, direct interchanges of ideas and interpretations have been effective in the development of a rational program for pollution abatement.

During the meetings since January, 1966, the PAC considered three important items:

1. Technical requirements associated with the implementation of a water pollution control plan.
2. Formal mechanism and time required by the state and interstate agencies in approving a water pollution control plan for the Delaware Estuary.
3. The establishment of a time schedule for construction of water pollution control facilities.

The DRBC has assumed much of the responsibility for organizing and directing the implementation of a pollution control plan. The DRBC will proposed a cooperative program to abate pollution involving all water resources people having responsibilities associated with the estuary.

The PAC members have also agreed to reach a consensus at a staff level to recommend a final set of water quality objectives. Their rationales will be primarily based on the requirements of the various state and federal laws and their interpretation of these laws.

2. Technical Advisory Committee (TAC)

The TAC has met on the average of once a month since its first meeting on June 6, 1963. The committee's formal business has included a review of all the technical programs carried out by DECS. Suggestions made by TAC members were carefully studied by all members concerned and, if agreed upon, incorporated into the work of the study.

The success of this committee was mainly due to the individual efforts of the members. Their conscientious review of DECS reports, procedures, and methodology was a major contribution in development of a technically sound pollution control program. Through the TAC major advances were made in the relationship between industry and the pollution abatement agencies. Industrialists were informed at a TAC industrial subcommittee meeting early in 1963 of the exact intentions of the DECS. An industrial waste effluent program was then initiated in association with a plan to obtain from each industry the costs of treating their wastes to several possible levels. The industrial community cooperatively hired an outside consultant, an expert in the field of water pollution control, to provide them with an independent appraisal of the DECS and methodology.

Through the TAC and PAC a cooperative river sampling program was developed. The Commonwealth of Pennsylvania and State of New Jersey contributed personnel to carry out bacteriological analyses and the State of Delaware contributed laboratory assistance. The DECS provided the personnel to make chemical analyses, directed the sampling program, and helped with the chemical and biological analyses. The City of Philadelphia and the State of Delaware provided boats and crews for special DECS bottom sampling study.

The City of Philadelphia also contributed to the DECS by providing equipment and personnel to help install and maintain combined sewer sampling and monitoring equipment. The City also maintained 21 rain gages installed around the City as part of the precipitation monitoring program.

3. The Water Use Advisory Committee (WUAC)

The work of the WUAC began with two formal meetings held with each of the four subcommittees, (Industry; General Public; Local Government and Planning Agencies; Recreation, Conservation, Fish & Wildlife). At these meetings the Project Director and Technical Director outlined the objectives of the study, the methodology being used, and explained what information the DECS desired of them. Each group then selected a chairman who would be their representative on the WUAC.

The first meeting of the WUAC was held on December 3, 1964. Since then, the committee has met on the average of once every 2-1/2 months. Usually the industrial subcommittee has met at least once and sometimes twice prior to each WUAC meeting. Meetings of the other subcommittees varied and much of their work was accomplished through correspondence.

The subcommittee chairmen spent many hours organizing, preparing material, reviewing reports, writing letters, making telephone calls in preparation for meetings, and in arriving at their final recommendations.

The committee's work in extracting water use and quality desires from their constituents was divided into two phases; Phase I consisted of eliciting from each organism the water use and quality needs and desires in a general narrative; they also specified water quality indicators if possible. The individual responses were summarized by the subcommittee chairmen and these four responses summarized by the DECS staff. The WUAC Phase I Report will be presented in Appendix IX of Part 2 of this report. Phase II of the WUAC work was intended to provide more information on the specific location of present and desired future water uses and specific ranges and/or values of individual quality parameters associated with each water use. This was an enormous challenge and was, therefore, divided into two steps: Step 1, the designation of present and future uses and the location of these uses along the length of the estuary; Step 2, associating levels of water quality parameters with the desired uses. Step 1 presented few problems to the subcommittees. The only obstacle came in the preparation of "Future Suggested Possible Uses." To insure that these desired uses were in fact "Suggested Possible" and that not all of these were approved by each subcommittee, it was requested that along with each desired future use a notation be added to show exactly which subcommittee was in agreement with it.

A great deal of difficulty was encountered in the preparation of Phase II-Step 2. Many of the organizations represented were not expert or even familiar with the language of the water pollution control field. The exceptions, of course, were the industrial subcommittee and Local Governments subcommittee who had professionals on their staffs. It was agreed on this basis that the DECS staff act as consultants to the non-technical groups in selecting ranges and values of quality parameters associated with water uses. Thus, at the request of the subcommittee chairmen the DECS staff helped to prepare much of the Phase II-Step 2 work for both the General Public and the Recreation, Conservation, Fish & Wildlife Subcommittees. All ranges and values selected, however, were submitted to all subcommittee members for final review and approval.

On the basis of the WUAC Phase I and Phase II reports, the DECS staff with the cooperation of the advisory committees prepared four water use/quality objective sets. These sets are found in Chapter 5, Page 56, Part 1. These objective sets list four possible levels of water quality enhancement in the Delaware Estuary. A fifth set was prepared to show the existing water use and quality conditions. The DECS staff prepared the costs and quantifiable benefits associated with each objective set, and reported these results in an interim report entitled "Report on Alternative Water Quality Improvement Programs".

These reports were submitted to the three DECS advisory committees and all subcommittee members. Through a long process involving numerous meetings, conversations, and correspondence, the chairmen of the WUAC extracted the viewpoints and expressions from their members and arrived at a consensus for their committee. At their eleventh meeting on March 28, 1966, the committee arrived at one compromised objective set as their final recommendation to the DECS. This final report is found as Appendix II of Part 1.

Several factors contributed to the lack of direct participation by many of the subcommittee members of all but the Industrial subcommittee. It should be pointed out that the members of the Industrial subcommittee were being paid while attending meetings; this was part of their job and their performance was excellent. Participants of the other subcommittees were mainly volunteers from various interest groups. In most cases these persons had to provide their own travel expenses to attend meetings besides having to take time off from their own jobs. The numerous citizens who did find time to attend meetings and review and analyze reports should be commended for their efforts.

The WUAC subcommittee chairmen devoted considerable effort in obtaining responses from their groups. In the final analysis it is thought that for the three subcommittees (excluding industry), the chairmen were able to obtain at least the general desires of their groups. Meetings of the Industry Subcommittee as indicated before were well organized, efficiently run, and well attended. As a result the response obtained from the industrial subcommittee represents the consensus of the industrial community. Using the response from each of the four subcommittees, the subcommittee chairmen were able to agree to a final set of water use/quality objectives (see Appendix II).

Some difficulty was experienced because of the technical and political complexity of the program. The DECS staff attempted to make the program objectives as clear as possible, but occasionally these objectives were obscured. One problem was the inability of non-technical oriented persons to comprehend many of the technical aspects of the program. The techniques used by the study were of such a complex nature that even the industrial community hired a consultant to verify many of the techniques which were being used. Another obscuring factor was the changing political environment relating to water pollution control. As a result of the interpretations of the legislation recently enacted, many persons believed that the whole study was merely an academic exercise and perhaps even the preliminary steps to enforcement procedures which would inevitably follow.

Most of the committee responsibilities are now complete; it remains to the state, interstate, and federal agencies to decide on the form and time sequence which implementation will follow.

APPENDIX II

WATER USE ADVISORY COMMITTEE
TO THE DELAWARE ESTUARY STUDY

FINAL RECOMMENDATION

1-13

WATER USE ADVISORY COMMITTEE

TO THE DELAWARE ESTUARY STUDY

REPORT ON FINAL WATER USE RECOMMENDATION

APRIL, 1966

The Water Use Advisory Committee, after many months of deliberation, analysis, and debate, has arrived at its final recommendation to the Delaware Estuary Study.

At the eleventh meeting on March 28, 1966, the committee reached a consensus to recommend OS-III to be used by the DECS in its development of a final water pollution control plan for the estuary.

The position taken by each of the WUAC subcommittee chairmen based on meetings and correspondence with the members of their subcommittee is indicated as follows:

Subcommittee	Objective Set Preferred
Industry	III
Local Governments and Planning Agencies	III
Recreation, Conservation, Fish and Wildlife	II
General Public	III

The following four summary statements indicate in greater detail the views of each subcommittee.

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GENERAL PUBLIC SUB-COMMITTEE
OF THE
WATER USE ADVISORY COMMITTEE
OF THE
DELAWARE ESTUARY COMPREHENSIVE STUDY

A SUMMARY STATEMENT

The following statement of water quality objectives chosen by this committee does not represent a unanimous agreement of the ten active citizen-group representatives but rather a consensus of the majority who attended the many meetings and/or otherwise responded to correspondence.

FIRST - DECS WATER QUALITY OBJECTIVE SET III (Three) Zoned is the basic choice from the group of five sets mainly because it reflects a 1 to 1 cost benefit ratio besides representing a marked improvement in the estuary water quality at a reasonable cost. The committee considers Objective Set III a "quality floor" below which it will not go.

SECOND - In addition to Objective Set III, the committee feels strongly that passage of anadromous fish would represent other benefits and standards which are desirable. To obtain this, Objective Set III plus $30 million to pay for aeration is sought by the group (rather than the major financial jump from O.S. III to O.S. II.)

THIRD - Water supply-oriented members of the committee although agreeable to O.S. III now, seek O.S. II after 1985 when fresh water supplies will be needed at Chester.

FOURTH - At the last meeting Committee Chairman was authorized to compromise with other subcommittee chairmen in reaching a multi-committee single choice of Objective Sets. However, he was directed not to agree to a compromise choice of less than Objective Set III.

Paul M. Felton
Chairman
General Public Subcommittee
Member
Water Use Advisory Committee

INDUSTRY SUBCOMMITTEE
OF THE
WATER USE ADVISORY COMMITTEE
OF THE
DELAWARE ESTUARY COMPREHENSIVE STUDY

A SUMMARY STATEMENT

Throughout the entire Delaware Estuary Comprehensive Study, Industry has endeavored to cooperate, analyze, develop meaningful costs and data and factually present their position.

As such, in Phase I, various industrial water uses have been described together with clarifying statements regarding industrial objectives and water quality indicators. It was clearly established that regardless of the present water quality of the estuary, Industry has in most cases provided waste treatment facilities and has likewise adapted their water use and treatment to existing sources. In all probability, Industry will continue to operate existing water (intake) treating facilities in essentially the same manner despite any estuary upgrading.

In Phase II of the Study, industrial parameters of water quality were suggested in accordance with industrial needs which likewise expressed continuity of position with the Phase I Report. Industry so stated in Phase II that although they were expressing their own operational needs, it was clearly recognized that the objective of this Study was to determine the overall needs, interests and benefits of all water use groups. As such, we have been more than willing to cooperate with all water users to develop water quality which is factually sound and economically practical for the entire Delaware River Estuary.

Although the results of the DECS cost/benefit studies have certainly not shown an economic driving force for improving the quality of the estuary waters, Industry realizes that this is but one facet of consideration. The need for recreation, fishing, boating, aesthetics and many other pressures have likewise been considered. As a result of these considerations, therefore, Industry stands ready to accept a zoned approach for treatment and to depart from their original Objective Set IV position and accept, as a maximum, the water quality as indicated in Objective Set III.

Although these water quality objectives are not essential to industrial operations and will require the expenditure of considerable industrial monies, we are willing to assist in establishing what we consider to be a reasonable approach. However, Industry, in assuming this position, qualifies it on the basis that it will lead to a final decision for Objective Set III by the Water Use Advisory Committee.

We are firmly against any standards higher than Objective Set III because we believe them to be unjustified and most uneconomical to the best interests of the entire Estuary Community.

William B. Halladay
Chairman
Industry Subcommittee
Member
Water Use Advisory Committee

LOCAL GOVERNMENTS AND PLANNING AGENCIES SUBCOMMITTEE
OF THE
WATER USE ADVISORY COMMITTEE
OF THE
DELAWARE ESTUARY COMPREHENSIVE STUDY

A SUMMARY STATEMENT

As requested, the following statement represents the general consensus of opinion of the Local Governments and Planning Agencies Subcommittee relevant to Delaware River Water Quality.

As Chairman of the above committee, I have been in communication with Mr. Benjamin Feldman, Levittown Municipal Authority, Mr. Victor Appleyard, City of Chester, Pa., Mr. William C. Henry, Chief Engineer, Public Works, Wilmington, Delaware, and Mr. Roger Scattergood, N.J. Bureau of State & Regional Planning, Trenton, N.J.

They have all stated that Objective Set III appears to be a reasonable Objective at this time. Since this Objective Set does not go beyond secondary treatment, the group feels that it can be attained. They also feel that anadromous fish might also survive at this level of water quality and that it would be foolish to go into Objective Set II at this time when there is not sufficient technical knowledge of tertiary treatment and other processes which would be required. Also, the cost of going from Step III to Step II would be considerable.

In all fairness to my committee, I should state that two of them mentioned that Set II could be a long range goal. No particular year mentioned.

As Philadelphia's representative to this committee, I feel that Objective Set III would be a tremendous stride to take, particularly when one considers that the needs of the City of Philadelphia are being satisfied as far as water supply and waste assimilation are concerned, relative to present water quality.

Since Philadelphia will bear a great portion of the cost, I do think their feelings should be given strong weight in reaching a decision.

Carmen F. Guarino
Chairman
Local Governments and Planning
 Agencies Subcommittee
Member
Water Use Advisory Committee

RECREATION, CONSERVATION, FISH AND WILDLIFE SUBCOMMITTEE
OF THE
WATER USE ADVISORY COMMITTEE
OF THE
DELAWARE ESTUARY COMPREHENSIVE STUDY

A SUMMARY STATEMENT

As chairman of the Recreation, Conservation, Fish and Wildlife Subcommittee and as its representative on the Water Use Advisory Committee, I intend to recommend Objective Set II as covering the objectives which our subcommittee wishes attained.

By recommending Objective Set II, I will not imply that Objective Set I should not be a long-range goal. My reasons for not insisting on Objective I are that techniques are not available in the foreseeable future which could reasonably guarantee the attainment of water quality standards as called for in Objective Set I.

The chairmen of the General Public, Industry, and Local Governments and Planning Agencies subcommittees, as members of the Water Use Advisory Committee, are recommending Objective Set III. I consider this to be a step forward, particularly since industry and local governments are not unhappy with the present water quality in the estuary.

I feel that by recommending Objective Set II, conservationists are going on record as recognizing that the water quality standards called for under that objective are not beyond reason and can be attained. If we insist on Objective Set I, we will be asking for something that cannot be attained under present conditions - at least not until new concepts in sanitary engineering come about.

Edmund H. Harvey
Chairman
Recreation, Conservation, Fish
and Wildlife Subcommittee
Member
Water Use Advisory Committee